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Technical Report 2008
August 2012

Santa Margarita Lagoon
Water Quality Monitoring Data

Final Report

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This report was prepared for the by the Environmental Sciences Branch (Code 71752) of the Research and Applied Sciences Division (Code 717), SPAWAR Systems Center Pacific (SSC Pacific).

Released under authority of
Martin Machniak, Head
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SB

EXECUTIVE SUMMARY

This report describes water quality monitoring data collected in the Santa Margarita Lagoon between 3 February 2010 and 8 February 2011. The data collection was a response to data needs identified by the San Diego Regional Water Quality Control Board's (SDRWQCB) Investigative Order R9-2006-0076, "Lagoons Total Maximum Daily Load (TMDL) Monitoring" related to potential eutrophication impairment. In particular, the Investigative Order directed the Santa Margarita Lagoon Stakeholder Group composed of Marine Corps Base Camp Pendleton (MCBCP), Naval Weapons Station Fallbrook, County of San Diego, California Department of Transportation, Riverside County Flood Control and Water Conservation District, City of Temecula, and City of Murrieta to conduct a yearlong water quality data monitoring effort to support a regional board-led TMDL modeling effort. After a failed effort to collect this dataset in 2008, the Stakeholder Group requested the Navy's Environmental Sciences Branch of the Space and Naval Warfare Systems Center Pacific (SSC Pacific) to conduct the sampling.

The Santa Margarita Lagoon sits entirely within the boundaries of Marine Corps Base Camp Pendleton. It forms up where the Santa Margarita River meets the Pacific Ocean just north of Oceanside, California. The western boundary of the lagoon is the beach berm that borders the ocean. The estuarine lagoon is usually open to the ocean through a limited section of berm, although there are occasions when the lagoon is effectively closed to exchange with the ocean. The eastern boundary of the lagoon is defined by the easternmost extent of maximum tidal influence, roughly 1.5 miles upstream. The Santa Margarita River feeding the lagoon drains roughly 750 square miles in northern San Diego and southwestern Riverside counties.

The primary objective of this project was to provide a long-term water quality dataset that can be used for calibrating a hydrodynamic and eutrophication numeric model of the lagoon. A secondary objective was to provide a long-term dataset that along with observations made in other studies could be used to gain a more complete understanding of lagoon dynamics and main physiochemical processes. This dataset helps develop lagoon-specific water quality objectives.

The general technical approach followed the work plan developed for the lagoon's TMDL Investigative Order (SCCWRP, 2007). The main technical element included collecting a one-year water quality data set using electronic sensors at a fixed station in the western, ocean-dominated lower lagoon. These data were collected between 3 February 2010 and 8 February 2011. Measurements included depth, temperature, conductivity, pH, and dissolved oxygen collected at 15-minute intervals.

The second technical element included a set of measurements made during month-long index periods in March and October. These measurements included collecting sensor data at a fixed station in the eastern river-dominated upper lagoon, collecting weekly discrete samples at both the lower and upper lagoon sensor monitoring sites, spatial mapping and discrete sampling along a longitudinal transect between the lagoon mouth and the Stuart Mesa Bridge, and a survey of benthic macroalgae along the shoreline.

Discrete water samples collected during the two index periods were analyzed for total suspended solids, ammonium, nitrate, nitrite, total particulate nitrogen, total dissolved nitrogen, ortho-phosphate, total dissolved phosphorous, total phosphorous, and total chlorophyll-*a*. All measurements were made using standard laboratory procedures. Additionally, nitrate, total nitrogen, dissolved organic nitrogen, and total particulate phosphorous concentrations were calculated from the measured values. Samples were also collected and analyzed for dissolved oxygen using a Winkler titration analytical method.

Spatial mapping was performed with a boat-mounted sensor system towed at the surface along a transect from the upper lagoon monitoring site to the lagoon mouth. Water quality sensor data were collected at 10-s intervals along with position data. Discrete samples were collected at 10 stations along the transect, including the two fixed-station sensor locations. Macroalgae percent cover and biomass were sampled along three transects locations during both index periods along the shoreline.

The main objective of this project, to provide a long-term water quality dataset of sufficient quality for calibrating a hydrodynamic and eutrophication numeric model for the lagoon, was met. The year-long depth, temperature, conductivity, pH, and dissolved oxygen dataset collected at 15-min intervals was sufficient to resolve variations at sub-tidal, daily, and seasonal time scales. The collection and analysis of discrete water samples for nutrients, total suspended solids, and chlorophyll-*a*, spatial mapping, and benthic macroalgal data during two index periods provided important calibration data for the modeling effort, insight as to sources and processes affecting their spatial and temporal distribution, and should in the future help in developing site-specific water quality objectives.

The dataset was not without some gaps and data issues. Most importantly, the data collection was interrupted for a month-long period in June during construction of an earthern berm to support a new railroad bridge in the lower lagoon. About a two-week data gap occurred when the sensor package was knocked out of the water during a set of intense storms in December. Benthic macroalgae data could not be collected once the lagoon mouth had closed October through December because the data needed to be collected at low tide. These data gaps could not be avoided. The bridge construction also led to a requirement to move the lower lagoon monitoring location half way through the data collection. The site was moved 600 feet upstream along the side of the lagoon. This second site was found to be generally representative of lower lagoon water quality for most parameters under open lagoon flow conditions. However, dissolved oxygen was lower than what might be found mid-stream during some periods of low/no-flow, particularly when the lagoon mouth was closed October through December. The results showed that some of the low (and zero) oxygen levels observed during a few weeks of the mouth closure, while accurate, were lower than what would have been observed in other parts of the lower lagoon. Additionally, total dissolved nitrogen and phosphorous and total particulate phosphorous were not measured during Index Period 2 were inadvertently not collected.

Despite the data gaps and issues, there were sufficient data to understand the main drivers of water quality occurring in the lagoon. The data describe a lagoon that was strongly dominated by its connection with tidal flow from the ocean. Daily fluctuations in water quality were primarily a result of tidal mixing of ocean water and river flow. Dissolved oxygen and pH fluctuations had a strong diurnal component which was consistent with diurnal algal production and respiration processes. The lack of tidal exchange during the mouth closure provided a dataset in which the primary daily variation was the diurnal signal.

The lagoon had strong seasonal variations in water quality conditions driven by decreasing freshwater flow, summertime heating, longer daylight hours, and a reduction in tidal flow as a result of natural berm building at the lagoon-ocean boundary. These effects were particularly strong when the mouth closed completely in October. The result was a lagoon that was considerably warmer and saltier with reduced freshwater flow and generally smaller daily variations in summer/fall than observed in winter/spring. The observed seasonal changes generally were much greater than the spatial variations observed between the lower and upper lagoon.

The main influence of ocean water exchange was observed to about the Railroad Bridge. The main influence of the freshwater river was observed about halfway between the Railroad Bridge and the Stuart Mesa Bridge. In between the two locations is a transition region where mixing of fresh and

saltwater is most intense. Previous spatial mapping surveys conducted during specific tide stages (SSC San Diego [now SSC Pacific], 2007) showed that the location of this transition region is not static, moving slightly up- or downstream with flood and ebb tide, respectively.

The observed seasonal changes in nutrient concentrations reflect changes in sources and uptake and transformations by the biota. Total nitrogen levels in the lagoon were significantly higher in March than in October. Nitrate made up an average of 69% of the total nitrogen with dissolved organic nitrogen making up an average of about 21%. The October levels of total nitrogen were about a factor of two lower and were on average made up of 54% dissolved organic nitrogen and about 40% particulate nitrogen, with nitrate making up only a 3% of the total. Concentrations increased moving upstream in March but there were no spatial trends during the time of lagoon closure in October. The shift in distribution, concentration levels, and speciation suggest that the winter/spring wet season was a time of nitrogen influx primarily as nitrate. As the dry season progressed, the upstream nitrate source was reduced and the remaining amount was further reduced through uptake by the algae. What was found in the lagoon in October was primarily organic and particulate nitrogen generated by the decomposition of the biota during higher algal productivity as observed by the increase in benthic macroalgae and as higher concentrations of chlorophyll-*a*.

About 80% of the total nitrogen concentrations found in March were above the Basin Plan limit of 1.0 mg/L, and primarily in the form of bioavailable nitrate-nitrogen. The October levels were all below the limit and were primarily in the less useable form of organic or particulate nitrogen. Transformation of this nitrogen would likely be a continuing source of nitrogen through the remainder of the year.

Total phosphorous levels in the lagoon were significantly higher in October than in March. Ortho-phosphorous on average made up roughly 60% of the total during both periods. In contrast to nitrogen, there was no spatial trend in phosphorous concentrations in March but October levels did increase upstream. The shift in distribution, concentration levels, and speciation suggest a continuing source of phosphorous into the lagoon in October above the assimilative capacity of the algae. Concentrations of total phosphorous were above the Basin Plan limit of 0.1 mg/L in all samples.

Lagoon chlorophyll-*a* and benthic macroalgal biomass concentrations increased significantly from March into October. Chlorophyll-*a* concentrations tripled in October while benthic macroalgal biomass went from near zero in March to between 40 and 100% cover later in the year. The increase in algae was a result of higher light, temperature, and nutrient loading along with a reduction in scouring that occurs during winter storms. The higher levels of primary production by the algae in October resulted in the lower level of total nitrogen concentrations in the water, and because of the increased respiration demand, resulted in lower dissolved oxygen daily minima. The levels in summer fell below the 5 mg/L water quality objective in the San Diego Basin Plan 16% of the time, primarily at night and very early morning.

Based on the Basin Plan limits of N, P, and dissolved oxygen, the lagoon can be classified as intermittently impaired from eutrophication. Nitrogen and phosphorous limits were exceeded in March. Phosphorous limits were also exceeded in October. Dissolved oxygen intermittently went below the 5 mg/L limit from spring to late fall. These results were relatively consistent with observations made in other studies (SSC San Diego [now SSC Pacific], 2007; CDM, 2009; SCCWRP, 2010). These other studies provide a similar picture of the overall findings described. Variations in annual river flow and/or nutrient loading adds to this variability. Lagoon modeling should provide the ability to capture the range in expected conditions and help in identifying under what conditions the Lagoon may be impaired. These nutrient predictions should provide a basis for establishing lagoon-specific water quality objectives.

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ACRONYMS

BOD	Biological Oxygen Demand
CFS	Cubic feet per second
Chl-*a*	Chlorophyll-*a*
CTD	Conductivity, Temperature, and Depth
DGPS	Differential Global Positioning System
DO	Dissolved Oxygen
DON	Dissolved Organic Nitrogen
DUP	Duplicate
EPA	Environmental Protection Agency
MCBCP	Marine Corps Base Camp Pendleton
NH_4-N	Ammonium Nitrogen
NO_3-N	Nitrate Nitrogen
NO_2-N	Nitrite Nitrogen
NCTD	North County Transit District
PO_4-P	Phosphate-Phosphorous
PHAEO	Phaeophytin
QA	Quality Assurance
QC	Quality Control
RPD	Relative Percent Difference
RR	Riprap site
RRB	Railroad Bridge
RSD	Relative Standard Deviation
SANDAG	San Diego Association of Governments
SCCWRP	Southern California Coastal Water Research Project
SSC PACIFIC	Space and Naval Warfare Systems Center Pacific
SDRWQCB	San Diego Regional Water Quality Control Board
SMB	Stuart Mesa Bridge
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorous
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TPN	Total Particulate Nitrogen
TP	Total Phosphorous
TPP	Total Particulate Phosphorous
TSS	Total Suspended Solids
USGS	United States Geological Survey

1. INTRODUCTION

This report describes water quality monitoring data collected in the Santa Margarita Lagoon between 3 February 2010 and 8 February 2011. The data collection was designed to fulfill requirements under the San Diego Regional Water Quality Control Board's (SDRWQCB) Investigative Order R9-2006-0076, “Lagoon’s Total Maximum Daily Load (TMDL) Monitoring” related to potential eutrophication impairment. In particular, the investigative order directed the Santa Margarita Lagoon Stakeholder Group composed of Marine Corps Base Camp Pendleton (MCBCP), Naval Weapons Station Fallbrook, County of San Diego, California Department of Transportation, Riverside County Flood Control and Water Conservation District, City of Temecula, and City of Murrieta to conduct a yearlong water quality data monitoring effort to support a regional board-led TMDL modeling effort.

The Stakeholder Group originally hired CDM (now CDM Smith) to conduct the lagoon monitoring in 2008–2009. The resultant discrete nutrient dataset provided to the stakeholders and regional board in 2009 (CDM, 2009) was of sufficient quality and quantity to support the order but the long-term records of dissolved oxygen and conductivity water were found to be deficient as stated in the data transmittal letter of 25 June 2009:

> “*Regardless, sonde discontinuities, coupled with only two or three calibration points, make the absolute values of the CDM sondes untrustworthy and difficult to use in model development.”*

In response to this deficiency, MCBCP requested the Navy’s Environmental Sciences Branch of the Space and Naval Warfare Systems Center Pacific (SSC Pacific) to collect a long-term continuous water quality dataset that could be used to meet the requirements of the order that were not met. The main elements of this data collection included a yearlong monitoring in the lower lagoon of key water quality components required for modeling (temperature, conductivity, dissolved oxygen) and spatial mapping of the same water quality constituents along with discrete nutrient data, once each during the spring and fall. The regional board requested that the stakeholders add data collection during two one-month index periods in the spring and fall. The additional data included monitoring continuous water quality data at a second upper lagoon site, weekly discrete nutrient analyses at both the lower and upper lagoon sites, and sampling for benthic macroalgae in both the lower and upper lagoon.

The overall data collection tasking was approved by the SDRWQCB and by the Southern California Coastal Water Research Project (SCCWRP), the board’s technical advisor on the investigative order. A Memorandum of Agreement was signed and executed by all stakeholders with funds provided for the additional monitoring according to percentages established for the 2008 sampling effort.

This report describes the technical approach, methods, and results of the data collection. The report also reviews other pertinent datasets to provide an evaluation of lagoon water quality, the dynamics and main physiochemical processes that control it, as well as provide insight on data collection techniques and data quality.

1.1 BACKGROUND

1.1.1 Location

The Santa Margarita Watershed encompasses approximately 750 square miles in northern San Diego and southwestern Riverside counties. The Santa Margarita River forms near the City of Temecula in Riverside County at the confluence of the Temecula and Murrieta Creek systems, one of the fastest growing areas in California. Once formed, the majority of the Santa Margarita River main

stem flows within San Diego County through unincorporated areas, the community of Fallbrook, and Marine Corps Base Camp Pendleton. Additional tributaries feeding the river include Sandia, De Luz, and Rainbow Creeks. The river forms up into an estuarine lagoon where it meets the Pacific Ocean just north of Oceanside, California (Figure 1).

The lagoon sits entirely within the boundaries of Marine Corps Base Camp Pendleton. The western boundary of the lagoon is the beach berm that borders the ocean. The lagoon is usually open to the ocean through a limited section through the berm, although there are occasions when the lagoon is effectively closed to exchange with the ocean. The eastern boundary of the lagoon is defined by the easternmost extent of maximum tidal influence. Though the exact location where this occurs is not accurately known, it does extend at least a short distance east of the Stuart Mesa Road Bridge (~1.25 miles upstream). Though the physical width of the lagoon at its western end is a maximum of about 0.5 miles wide, only about half of that distance is wetted during non-storm conditions. The lagoon quickly narrows to the east to roughly 1/10th of its maximum width where the north- and south-bound lanes of Interstate 5 cross over it.

1.1.2 Physical Setting

The lagoon is very shallow with depths typically less than 3 feet and an approximate maximum depth of about 6 feet at high tide. A large portion of the lagoon is not wetted at low tide. The lagoon is subject to year-round inflow of freshwater from Santa Margarita river, averaging 5.5 cubic feet per second (cfs) based on the United States Geological Survey gauge data collected about 5 miles upstream (United States Geological Survey (USGS) 11046000 SANTA MARGARITA R A YSIDORA CA). Maximum inflows occur during winter storms where maximum flows have reached as high as 44,000 cfs. When open, the lagoon is influenced by semi-diurnal tides that typically result in two high and two low water periods a day. Thus, the ocean has a strong influence on lagoon hydrodynamics and basic water quality parameters. Previous monitoring of water quality in the lagoon (SSC San Diego, 2007) showed that this ocean influence results in a steep longitudinal gradient in water quality parameters in the vicinity of the Railroad Bridge that can be thought of as a transition from a western ocean-dominated lower lagoon segment to an eastern river-dominated upper lagoon segment.

The sediments of the lagoon are mostly sand (55 to 86%). Large storms can bring in large amounts of sediment and rework large areas so that the bottom contours can change greatly from year to year. These storms act to keep the mouth open though long-shore drift along the coast tends to work toward narrowing or closing the mouth through the summer and fall. These competing forces alter the size and location of the mouth, including its occasional complete closure. When this occurs, lagoon sediments remain wetted and water depths increase with the inflow of freshwater.

1.1.3 Water Quality

The lagoon was listed as impaired for eutrophication by the SDRWQCB in 1998. As a result, the lagoon along with 10 other lagoons along the southern Californian coastline were subject to an investigative order (R9-2006-076) to obtain water quality data that would be used to evaluate the extent of impairment as well as provide sufficient data for developing watershed and lagoon numerical models for managing lagoon water quality through implementation of a TMDL program.

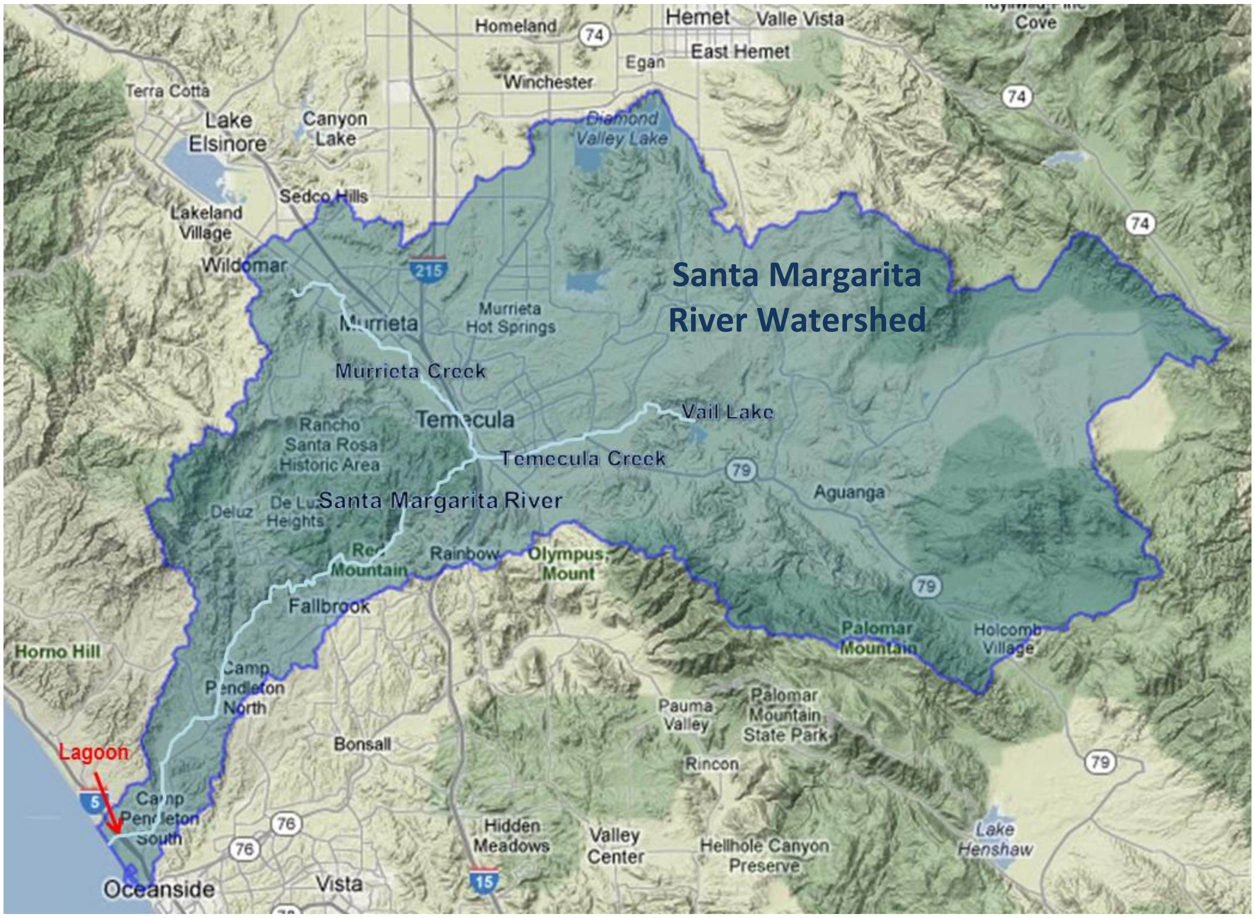


Figure 1. Santa Margarita River Watershed. The lagoon is at the southwestern end of the watershed within Marine Corps Base Camp Pendleton north of Oceanside, California.

1.2 OBJECTIVES

The primary objective of this project was to provide a long-term water quality dataset that can be used for calibrating a hydrodynamic and eutrophication numeric model of the Santa Margarita Lagoon. The project objective therefore meets the requirements of the SDRWQCB investigative order. Additionally, the long-term observations along with those made in other studies should provide a more complete understanding of lagoon dynamics and main physiochemical processes that affect lagoon water quality on daily, seasonal, and annual scales. This dataset should help in the development of site-specific water quality objectives. Future modeling of the lagoon will be conducted to identify potential management options that could be undertaken to maintain or improve future water quality in the lagoon.

2. METHODS

2.1 TECHNICAL APPROACH

The general approach used to collect data in the lagoon followed that of the investigative order as well as the work plan and general quality assurance (QA) elements developed for the investigative order by the Southern California Coastal Water Research Project (SCCWRP, 2007). The basic elements included collecting a 1-year water quality data set using electronic sensors at a fixed station in the western ocean-dominated lower lagoon at, and near to the Railroad Bridge. Additionally, sensor data were collected at a fixed station in the eastern river-dominated upper lagoon at the Stuart Mesa Bridge during month-long index periods in the winter/spring and in the summer/fall. Both stations were located near the sites used by CDM during the 2008–2009 sampling. The two index periods were designed to capture both wet season and critical-period dry conditions. During the two index periods, discrete water samples were collected at both fixed-station locations weekly and analyzed for nutrients, total suspended solids, and chlorophyll-*a*. Spatial mapping of the lagoon surface water was also conducted along a longitudinal transect between the lagoon mouth and the Stuart Mesa Bridge once each index period. The mapping included high-resolution data collection using electronic sensors along with discrete water samples analyzed for nutrients. An additional element not originally included in the investigative order work plan that was recommended for inclusion by SCCWRP and the SDWRQCB was sampling for benthic algae during each Index period.

2.2 GENERAL PROJECT CHRONOLOGY

Field data collection began in the lagoon on 3 February 2010 and terminated on 8 February 2011. Collection started with the placement of a multiparameter sensor probe onto the northwest strut of the Railroad Bridge (Figure 2). This site was approximately 300 feet west of the site used by CDM and was placed in midstream versus right along the shoreline (Note: the distance is based on personal visual observation as the actual latitude–longitude data in the CDM report were never described). This long-term data collection was interrupted twice during the yearlong period. The probe was pulled out of the lagoon entirely between 7 June and 7 July 2010 while the San Diego Association of Governments (SANDAG) built an earthen berm across the lagoon to support construction of a new Railroad Bridge (RRB) shown in Figure 3. The construction berm, which was built directly on top of the original location of the sensor probe extended roughly one-third of the way from each embankment, leaving a gap about one-third the width of the estuary through the middle. After the month-long construction period, the probe was placed back into the water off an area of riprap on the southern shore approximately 600 feet further upstream from the original site (Figure 2). This site was designated the lower lagoon Riprap (RR) site. The sensor remained at that site until the field work terminated on 8 February 2011. The lagoon mouth was effectively closed between ~1 October and 20 December 2010 as a result of natural sand buildup of the beach berm at the lagoon mouth, thus eliminating exchange with the ocean. Macroalgae sampling was not possible during this time because there was no low-tide condition. A weeklong group of storms starting on 16 December 2010 dropped approximately 6.6 inches of rain that created sufficient flow to break open the beach berm, which once again allowed exchange with the ocean. The monitoring probe was knocked out of the water during the exceptionally high flows and conditions prevented the crew from resetting the instrument into the water for a 13-day period (16 December 2010 to 4 January 2011).

The two one-month long index periods occurred between 5 March and 8 April 2010 and between 20 September and 19 October 2010. During these time periods, a second multiparameter sensor probe was placed on a midstream support of the Stuart Mesa Bridge (Figure 2). This site was

approximately 50 feet west of the site used by CDM and was placed in midstream versus right along the shoreline (Note: the distance is based on personal visual observation as the actual latitude–longitude data in the CDM report were never described). Note that this second site was monitored between 10 March and 8 April 2010. Discrete water sampling and analysis was conducted weekly at both fixed stations during each index period. One spatial mapping and benthic algae survey were also conducted during each index period. Note that the discrete sampling for the two periods was conducted on 5, 10, 17, and 24 March 2010 and then again on 9 September, and 6, 12, and 19 October 2010.

Figure 2. Field work region of the Santa Margarita Lagoon between the Pacific Ocean and Stuart Mesa Bridge. Interstate 5 cuts across the lagoon at roughly the midpoint of the work area. The red dots (●) indicate fixed-instrument monitoring sites. The initial Railroad Bridge (RRB) location had to be moved to the Riprap (RR) location when construction on a new bridge started in June 2010. The two sites were monitored continuously over a 1-year period. The Stuart Mesa Bridge (SMB) site was monitored only during two month-long index periods. Photo supplied by Google Earth.

2.3 WATER QUALITY MONITORING

2.3.1 Sensor Data Collection

Electronic sensors were used to measure water quality parameters including dissolved oxygen, temperature, salinity, depth, and pH at fixed locations in the lagoon. The lower lagoon was monitored over a 1-year collection period of 3 February 2010 to 8 February 2011, while the upper lagoon was monitored only during two one-month long index periods (5 March and 8 April 2010 and between 20 September and 19 October 2010). The instruments were affixed to the downstream side of the northern bridge support of the Railroad Bridge and a mid-stream bridge support of the Stuart Mesa Bridge (Figure 4). The Railroad Bridge position as determined with a Differential Global Positioning System (DGPS) receiver was 33.23567°N, 117.40677°W. The Stuart Mesa Bridge location was 33.23762°N, 117.39529°W. The two sites represent the SDRWQCB's Segment 1 (lower lagoon) and Segment 2 (upper lagoon) monitoring locations, respectively. The sensor at the Railroad Bridge was moved

~600 feet upstream to a site along the southern shore Riprap site (Figure 5) when construction of a new bridge began in June 2010. The position of this site was 33.23543°N, 117.40430°W. All three site locations are summarized in Table 1.

Figure 3. Photo of Railroad Bridge construction. The berm on the right side of the photo was where the sensor package was mounted before it was moved further east to the Riprap site.

An In-Situ Inc. Troll 9500 multiparameter water quality sensor package was deployed at the Railroad Bridge and Riprap sites. A Hach Company Hydrolab MS5 multiparameter water quality sensor package was deployed at the Stuart Mesa Bridge. Both instruments were set up to measure conductivity (µS/cm), Salinity (psu), Temperature (°C), Depth (cm), and Dissolved Oxygen (mg/L and % saturation). Conductivity values were corrected for temperature and reported as Specific Conductivity at 25 °C.

The Troll 9500 unit was also used to measure pH. Both instruments were set up to collect data at 15-minute intervals. The units were placed deep enough to complete submersion during all tidal stages. The Troll package depth had to be adjusted on a couple of occasions when (most notably on 14 March) a combination of reduced river flow and neap tides resulted in insufficient depth for all sensors. The Troll unit at the Railroad Bridge location was replaced by the Hach between 6 and 20 May while the Troll depth sensor was repaired.

The Troll was monitored daily using a Web-based telemetry system (In Situ, Inc.) that provided hourly data reporting. Daily monitoring ensured that the system was operational and working within expected parameters and allowed problems to be quickly identified and corrected. Data were monitored through the entire period in this manner though the 15-minute data stored within the field unit was downloaded each visit and used for the final analysis.

Table 1. Fixed-station locations.

Location	Longitude (Degrees West)	Latitude (Degrees North)
Railroad Bridge (RRB)	117.40677	33.23567
Riprap (RR)	117.40430	33.23543
Stuart Mesa Bridge (SMB)	117.39529	33.23762

2.3.2 Quality Assurance/Quality Control (QA/QC)

Quality assurance requirements for this project generally followed those developed for the investigative order by SCCWRP in 2007 and CDM in 2007. A separate formal Quality Assurance Project Plan was not developed. Sensor packages were calibrated prior to and after their deployments and checked monthly (weekly during index periods) in the field using techniques that expanded on the manufacturer's suggested single point calibration procedures. Calibrations included validations of multiple varying conductivity and pH solutions, as well as 0 and 100% saturated oxygen solutions to ensure that the full range of expected values was measured accurately. The response to pH was tested against buffer solutions of pH 7 and 10 to bracket the expected values of pH in the lagoon.

Measurements of dissolved oxygen (DO) were verified against 18 Mega-ohm/cm water under 100% DO saturation conditions by bubbling air, or 0% DO conditions through the addition of sodium bisulfite. Conductivity was verified by response to a standard solution of 0 and a high conductivity standard of ~50,000 µS/cm and occasionally a dilution series of the standard. Sensors were deemed "within calibration" if the measured values were within 5% of a standard solution value. The sensors were commonly within a couple percent of the standard value and only conductivity had to be recalibrated when deploying the system or after a new sensor was installed. Additionally, discrete water samples were collected and analyzed for dissolved oxygen using a standard Winkler titration method (APHA, AWWA, and WPCF, 1989) to compare to instrument measurements. Calibration tables and field data logs (typed and original scanned logs) are provided in Appendix A on the accompanying CD.

The Troll system had a calculation flaw that was discovered prior to the start of monitoring. The calculation of dissolved oxygen used a fixed value of conductivity (either entered manually or using a value measured at the time of deployment) rather than the real-time value. The impact is negligible when water conductivity is near constant, but can be in error by as much as 4 mg/L when working in estuaries that fluctuate as a result of freshwater and ocean water flows. The correction lowered the reported value of dissolved oxygen as a function of increasing salinity. The flaw was discussed with the manufacturer who then provided the appropriate algorithms to correct the data using measured conductivity. All data were corrected using this algorithm.

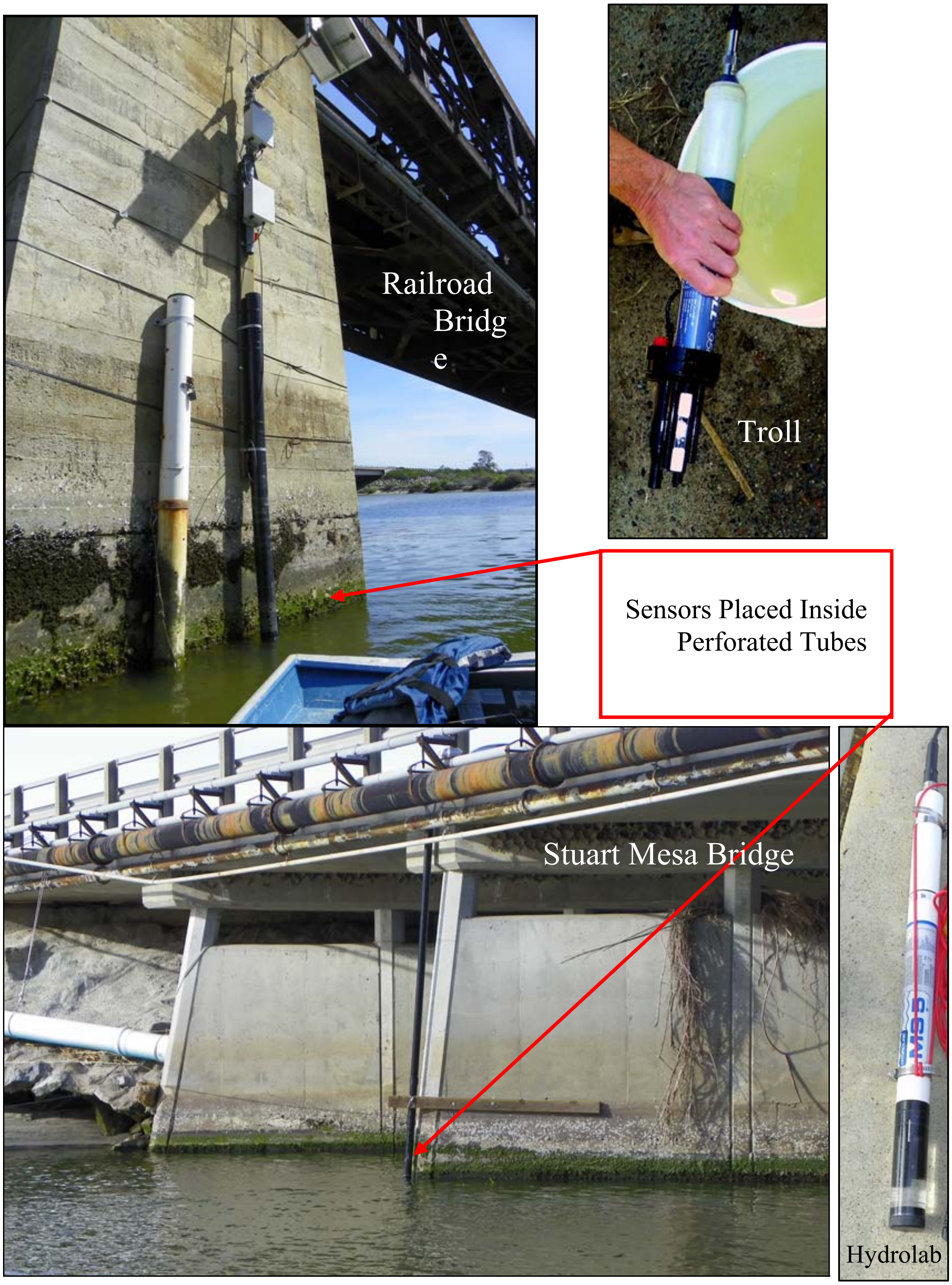


Figure 4. Sensor installations at Railroad Bridge (top photo) and Stuart Mesa Bridge (bottom photo). Sensors were placed inside perforated PVC tubes for protection.

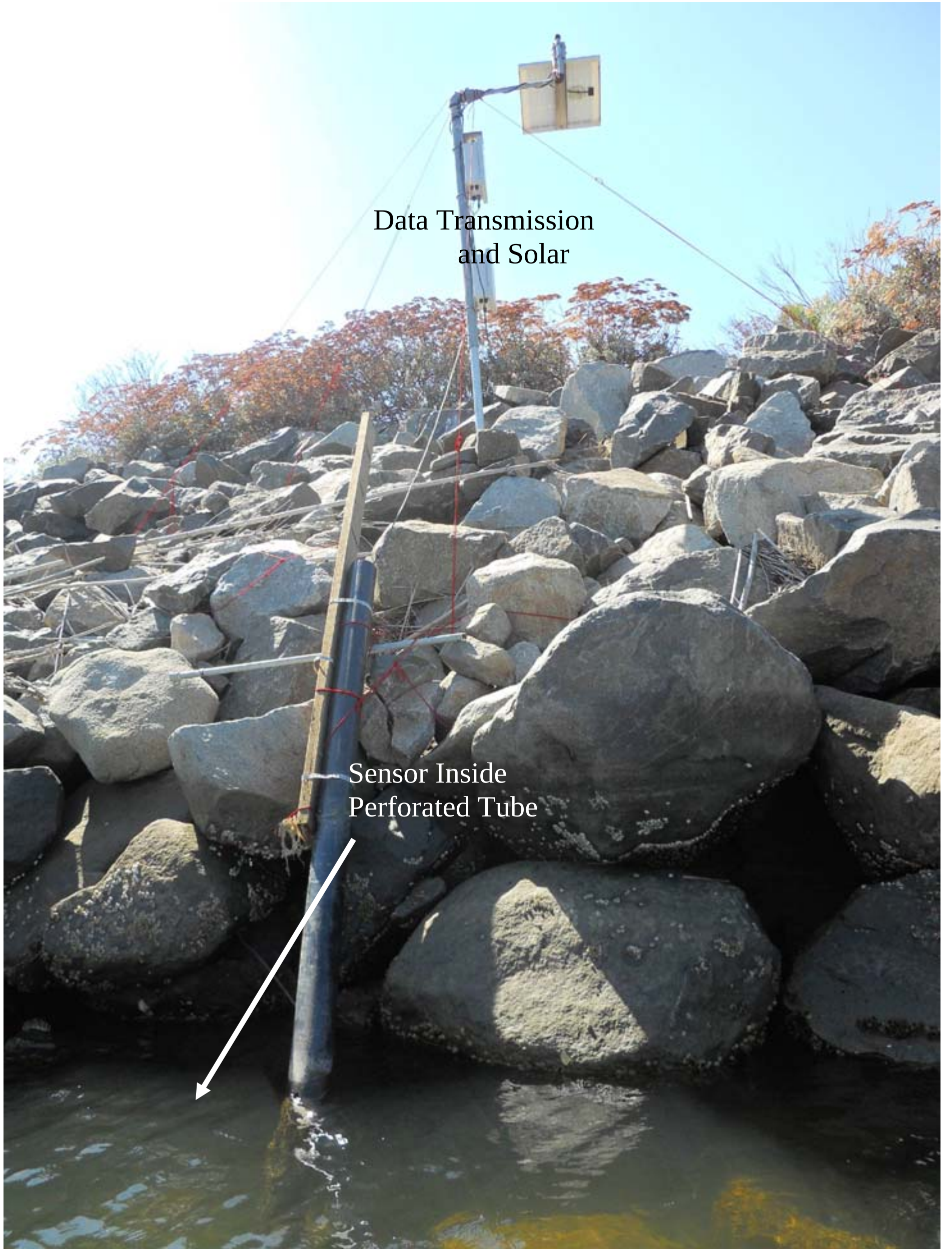


Figure 5. Sensor installation at the Riprap site on the southern shore of the lower lagoon.

2.4 DISCRETE WATER SAMPLE COLLECTION AND ANALYSIS

2.4.1 Sample Collection

Discrete water samples were collected to test for nutrients, dissolved oxygen (DO), chlorophyll-*a* (Chl-*a)*, and total suspended solids (TSS) once per week at each sensor location during the two Index periods. They were also collected at an additional eight locations along the spatial mapping transect during the two Index periods. Sample collection dates for the first Index period were 5, 10 (spatial mapping), 17, and 24 March 2010. Sample dates for the second Index period were 28 September and 6, 12 (spatial mapping), and 19 October 2010.

Nutrient measurements included: ammonium (NH4-N), nitrite (NO2-N), nitrite+nitrate (NO2+NO3-N), total particulate nitrogen (TPN), total dissolved nitrogen (TDN), ortho-phosphate (PO4-P), total dissolved phosphorous (TDP), and total phosphorous (TP). Additionally, nitrate (NO3), total nitrogen (TN), dissolved organic nitrogen (DON), and total particulate phosphorous (TPP) concentrations were calculated from the measured values (see Table 3 for the specific calculations). Dissolved total nitrogen and dissolved total phosphorous were not analyzed on samples collected during the Index Period 2 sampling because of a miscommunication with the analytical laboratory. A summary of dates and locations for the samples collected is shown in Table 2. Sample names were altered slightly from those used in the field to simplify their use in this report.

Water samples were collected using a persistaltic pump at a depth of approximately 0.5 m. Water was placed into three 1-L polyethylene bottles for subsequent processing as well as into 300 mL Biological Oxygen Demand (BOD) glass bottles for Winkler dissolved oxygen titrations. Each bottle was rinsed three times with lagoon water prior to sample collection. Oxygen in samples collected for Winkler titration was chemically fixed immediately through the addition of manganese sulfate and potassium iodide in potassium hydroxide (APHA et al., 1989), and kept from direct sunlight. All other samples were kept in the dark and on ice in coolers until processed at the SSC Pacific laboratory.

Water samples were processed for nutrients, Chl-*a*, and TSS in accordance with post sampling processing methods provided by University of Maryland. In short, for Chl-*a* and TSS sample water volume sufficient to cause a substantial change in color (approximately 980ml for TSS and 500 mL for Chl-a) was filtered through a filter rig with the pre-weighted 47 mm rig and filter pad. The pad was then rinsed with deionized water (TSS only) and placed in a pre-labeled foil pouch. Approximately 125 mL of the filtrate from the Chl-*a* filtration was used to fill the precleaned 125mL polypropylene collection vial for nutrient analysis. Approximately 25 mL of unfiltered sample water was added to a 30 mL polypropylene bottle for TP and TN analysis. Approximately 100 mL of sample was filtered through a 25 mm rig and pads for TPN analysis. Samples were rinsed with deionized water and placed in pre-labeled foil pouches. This process was repeated twice per sample. Following sample processing all samples were placed at -20°C until shipping.

2.4.2 Quality Assurance/Quality Control (QA/QC)

Sample collection procedures included using pre-cleaned bottles and sampling equipment and pre-rinsing all materials with sample water prior to capture. Samples were stored in the dark on ice and processed within a few hours of collection in clean laboratory conditions to ensure consistency and less chance of contamination. All processed samples were kept frozen until analysis.

2.4.3 Analytical Methods

2.4.3.1 Nutrients. The University of Maryland Chesapeake Biological Laboratory, Solomons, Maryland, performed the nutrient analysis. The analyses were planned to be the same for both index periods, but a mix-up with the laboratory resulted in a slight change in the analytes that were measured and/or calculated. The differences are shown in Table 3. The differences of the analysis type and its impact on the data are described in the QA section.

An alkaline persulfate digestion procedure was used to determine total N/P and/or total dissolved N and P, as well as organic and inorganic forms of N and P. For each sample, the organic N concentration was calculated by subtracting the sum of ammonia and nitrite+nitrate concentrations from the total dissolved N. The nutrients measured along with their EPA method numbers are provided in Table 3. References for these methods are included in the Reference section. All nitrogen

and phosphorous species concentrations were reported as nitrogen equivalents (-N suffix) and phosphorous equivalents (-P suffix).

Table 2. Summary of discrete water samples collected and analyzed for nutrients, TSS, Chl-a, and DO by Winkler titration. The sample naming convention is shown at the bottom of the table. Note that sample names described here vary slightly from those used originally in the field logs to simplify the reporting (Appendix A). The fourth sample in each index period was collected during the spatial mapping surveys (second sample in Index Period 1, third sample in Index Period 2).

INDEX 1

SAMPLE ID	DATE	Time
Lower Lagoon - Railroad Bridge		
SM-I1-D1-RRB	03/05/2010	0928
SM-I1-D3-RRB	03/17/2010	1013
SM-I1-D4-RRB	03/24/2010	1115
Upper Lagoon - Stuart Mesa Bridge		
SM-I1-D1-SMB	03/05/2010	1312
SM-I1-D3-SMB	03/17/2010	1236
SM-I1-D4-SMB	03/24/2010	1200
Spatial Mapping		
SM-I1-D2-S1	03/10/2010	0955
SM-I1-D2-S8	03/10/2010	0940
SM-I1-D2-S11	03/10/2010	0925
SM-I1-D2-S15	03/10/2010	0913
SM-I1-D2-RRB	03/10/2010	0857
SM-I1-D2-S21	03/10/2010	0831
SM-I1-D2-S22	03/10/2010	0823
SM-I1-D2-S24	03/10/2010	0808
SM-I1-D2-S26	03/10/2010	0740
SM-I1-D2-SMB	03/10/2010	0722

INDEX 2

SAMPLE ID	DATE	Time
Lower Lagoon - Riprap Site		
SM-I2-D1-RR	09/28/2010	1100
SM-I2-D2-RR	10/06/2010	1147
SM-I2-D4-RR	10/19/2010	1051
Upper Lagoon - Stuart Mesa Bridge		
SM-I2-D1-SMB	09/28/2010	1305
SM-I2-D2-SMB	10/06/2010	1319
SM-I2-D4-SMB	10/19/2010	0915
Spatial Mapping		
SM-I2-D3-S1	10/12/2010	1108
SM-I2-D3-S8	10/12/2010	1050
SM-I2-D3-S11	10/12/2010	1040
SM-I2-D3-S15	10/12/2010	1029
SM-I2-D3-RR	10/12/2010	1013
SM-I2-D3-S21	10/12/2010	0853
SM-I2-D3-S22	10/12/2010	0841
SM-I2-D3-S24	10/12/2010	0810
SM-I2-D3-S26	10/12/2010	0800
SM-I2-D3-SMB	10/12/2010	0750

SM = Santa Margarita

I = Index

D1-D3 = Repeat visit during Index

RR = Riprap site

RRB = Railroad Bridge

SMB = Stuart Mesa Bridge

Snn = Station Number

2.4.3.2 Suspended Solids. Samples were analyzed for TSS using the standard operating procedure 1.06, "Standard Operating Procedure: Water Sample Filtration and Analysis for Total Suspended Solids, Chlorophyll and Phaeopigments," developed at the University of New Hampshire Jackson Estuarine Laboratory. Analysis was performed by filtering approximately 500 mL through pre-dried and pre-weighed glass-fiber filters (1.2-µm nominal pore size). The filters were rinsed with deionized water to remove dissolved salts, then dried and weighed to determine the mass of the filtered solids.

2.4.3.3 Chlorophyll. Samples were analyzed for Chl-*a* using standard techniques described in ASTM (1995). Approximately 100 mL of water was filtered through microfiber filters and the filtrate extracted in 90% acetone. The solution was analyzed in triplicate on a Turner Designs Model 10 fluorometer that was calibrated against a Chl-*a* reference standard. The sample was analyzed before and after acidification with hydrochloric acid to account for pheophytin interference.

2.4.3.4 Winkler Oxygen. Measurement of dissolved oxygen in the discrete samples was done following the azide modification to the Winkler titration (APHA, AWWA, and WPCF, 1989). This modification is used for most wastewater, effluent, and stream samples when more than 50 µg/L of nitrites are expected. In short, the azide method included fixation of the dissolved oxygen in the sample by addition of manganese sulfate and an alkali-iodide-azide reagent at the time of collection. In the laboratory, 1 mL of concentrated sulfuric acid was added once the precipitate had settled to approximately half the bottle volume. Concentrated phosphoric acid was used after May 6 when it appeared that there might be interferences by iron (III) causing a bias (high in the Winkler results. Replicates run with both acidification methods showed a slightly lower, though not significantly different average value ($p>0.05$) with phosphoric acid (5.78 ±0.97 mg/L versus 6.61 ±0.62 mg/L with sulfuric acid so phosphoric acid was used for the remainder of the analyses. The acidified sample was well mixed and an aliquot of 201 mL was titrated with standardized 0.025M sodium thiosulfate in the presence of starch. The concentration of dissolved oxygen in mg/L was calculated from the volume of sodium thiosulfate used to bring the yellow acidified sample to a clear endpoint.

2.4.4 Quality Assurance/Quality Control

A continuous-flow analytical technique was used for analysis of nitrate+nitrate, nitrite, ammonium, chloride, sulfate, nitrogen, and phosphates/phosphorus. Standards were made from appropriate dry reagents and calibrating standard solutions were run in each analytical batch. Laboratory duplicates, laboratory spikes, control samples, and documentation of the response slope were also used for quality assurance. The Chesapeake Biological Laboratory Nutrient Analytical Services Laboratory also participates in cross-calibration exercises, as part of Good Laboratory Practices standards, to ensure laboratory performance. Standard operating procedures for these analyses can be found on the lab website (http://www.nasl.cbl.umces.edu/).

Dissolved oxygen concentrations measured by Winkler titration in this project covered a range of from 0.00 to 10.57 mg/L (n=58), with an average of 7.03 ±2.43 mg/L. Duplicate or triplicate analyses of field samples (n=51) had an average relative standard deviation (RSD; standard deviation/average) value of 3.2% with a range between 0.2 and 16.8%.

2.5 SPATIAL MAPPING

Spatial mapping of lagoon water quality was conducted by towing the Troll multiparameter sensor package on the side of an electric powered small boat on an east-west transect from the Stuart Mesa Bridge to the lagoon mouth (Figure 6). Mapping was conducted during an ebb tide condition on 10 March 2010 between ~0715 and 1000 and on a flood tide on 12 October 2010 between ~0750 and 1110. The exact transect route was dictated primarily by water depths that were commonly less than 2 feet. The Troll sensor package was removed from the Railroad Bridge station for mapping during the first Index period but a second Troll was used during the second Index period. The system was set to collect data at 10-sec intervals continuously along the transect at a nominal depth of 20 cm. The instrument depth was set by suspending it from a float (boogie board). Sensor measurements included water depth, conductivity, salinity, temperature, dissolved oxygen, and pH. Position data were collected using a DGPS measuring at 2-s intervals. A power failure on the DGPS data logging unit during the first Index mapping resulted in manually recording position data from the unit at 1 to

2-min intervals for the remainder of the mapping. The along track spatial resolution of the water quality data collection was approximately 5 m. The data were downloaded to computer and calibration checks performed at the end of each survey.

Discrete water samples were collected at 10 stations along the transect for nutrients, TSS, Chl-a, and DO including those collected at the Stuart Mesa and Railroad Bridge fixed stations. The boat was stopped at each station during sample collection (Table 4). Station numbers correspond to previous SSC Pacific surveys conducted in 2007 (SSC San Diego [now SSC Pacific], 2007). Variations in position were mostly a result of accessibility of sufficient water depth. A peristaltic pump was used to collect the water into three 1-L sample bottles and two 300-mL glass BOD titration bottles. Water samples were kept in the dark and on ice in coolers then processed similarly as described in the previous section.

2.5.1 Quality Assurance/Quality Control

Instrument calibrations and graphical review of the data for consistency were used to evaluate instrument QA/QC. Discrete water sampling and analysis quality was evaluated using standard laboratory controls as described previously. Additionally, discrete water samples were collected and analyzed for dissolved oxygen using a standard Winkler titration method (APHA et al., 1989) to compare to instrument measurements.

2.6 BENTHIC ALGAE SAMPLING

2.6.1 Collection

Benthic and floating macroalgae transect sampling was conducted using methods developed by SCCWRP in their Estuarine Eutrophication Assessment Field Operations Manual, 2008. Three transect locations (Figure 7) were selected based on those previously used for the Southern California Bight Regional Marine Monitoring Program in 2008 (SCCWRP, 2008). The benthic surveys were conducted on 17 March 2010 and again on 9 October 2010. The three transects (T1, T2, and T3) were laid out parallel to the shoreline roughly a quarter of the way out between the shore and water line. The transect lengths during the first Index period was 50 m. The transect lengths during the second Index period was shortened to 10 m because water levels were too high after the mouth had closed up, effectively eliminating low tide conditions. Because of the elevated water level, only floating macroalgae were sampled on the second Index period. Further, Transect 3 was completely inaccessible. Station numbers and coordinates for the start and end of each transect are shown in Table 5. Variations in transect location for the two visits were a result of their accessibility by foot, amount of vegetation, and by water levels (Figure 8).

Two types of measurements of benthic biomass were made along each transect. The first, percent cover was made using the point intercept method within a 0.5 x 0.5 m PVC quadrat placed onto the surface at 5-m increments along the transect. An example of a quadrat placed on the sediment surface is shown in Figure 8. Percent cover was calculated based on the presence or absence of biomass at each of the 49 intersection points within the quadrat. Percent cover for the transect was based on the average value calculated for the entire transect. The second type of measurement, macroalgal biomass was made by collecting algae into a biomass delineator placed at the center of each of five (out of ten) 0.5 x 0.5 m PVC quadrats (Figure 8). The biomass was removed from within the delineator and placed into a pre-labeled Ziploc® bag and stored on ice until processed in lab. Floating macroalgae was evaluated in similar fashion but only at the furthest upstream and downstream ends of the transect. Floating macro-algae were sampled within each quadrat by placing the delineator in the center at a 5-cm depth and cutting away the top 5 cm of the algae with scissors. An end-cap was placed under the water surface away from the quadrat and bringing up to the surface underneath the

delineator to capture the material. Samples were placed into a pre-labeled Ziploc® bag and kept in the dark and on ice in coolers until processed in lab.

2.6.2 Analysis

Processing of marcroalgal samples was conducted in accordance with methods provided by SCCWRP for the Bight 2008 Survey. All samples were transferred to a -4°C refrigerator upon arrival at the laboratory. Samples were processed within 48 hours of collection. Each sample was carefully removed from Ziploc® bag and processed individually. Samples were cleaned by floating them in seawater to remove any mud and debris and then rinsed with DI water to remove salts. Excess water was removed. Samples were then placed individually into pre-weighed dishes to determine wet weights, dried in an oven, then reweighed to determine their dry weights.

2.6.3 Quality Assurance/Quality Control

Benthic Algae sampling was conducted in accordance with previously established methods for the Southern California Bight 2008 Regional Marine Monitoring Survey (SCCWRP, 2008). Proper procedures were followed to avoid contamination including walking outside of transect zone until collection was complete, and using individual Ziplock® bags for sample collection.

Table 3. Discrete water sample nutrient analyses were performed by the University of Maryland System Center for Environmental Science Chesapeake Biological Laboratory Nutrient Analytical Services Laboratory. Dissolved oxygen was analyzed by SSC Pacific. Note that there were slight differences in the analyses/calculations performed during each index period because of a result of a mix-up with the analytical laboratory.

Analyte	Method Index 1	Method Index 2
Nitrate+Nitrite-N (NO_2+NO_3)	Cadmium Reduction EPA Method 353.2	Same
Nitrite-N (NO_2)	Sulfanilamide EPA Method 353.2	Same
Ammonium-N (NH_4)	Bertholet Reaction	Same
Total Dissolved Nitrogen (TDN)	Persulfate Digestion on Filtrate	**Calculated=TN-TPN**
Total Particulate Nitrogen (TPN)	CHN Analysis on Filtered Particles	Same
Total Nitrogen (TN)	Calculated=TPN+TDN	**Persulfate Digestion**
Dissolved Organic Nitrogen (DON)	Calculated=TDN-(NO_3+NO_2+NH_4)	**Calculated=Calc TDN-(NO_3+NO_2+NH_4)**
Total Phosphorous (TP)	Ammonium Molybdate and Potassium Antimony EPA Method 365.1	Same
Total Dissolved Phosphorous (TDP)	Alkaline Persulfate EPA Method 365.1	**Missing**
Orthophosphate-P (o-P)	Alkaline Persulfate EPA Method 365.1	Same
Total Particulate Phosphorous (TPP)	Calculated=TP-TDP	**Missing**
Chlorophyll a (Chl-*a*)	Acetone Extraction EPA Method 445.0	Same
Total Suspended Solids(TSS)	Gravimetric EPA Method 160.2	Same
Dissolved Oxygen (DO)	Sensor and Winkler Titration	Same

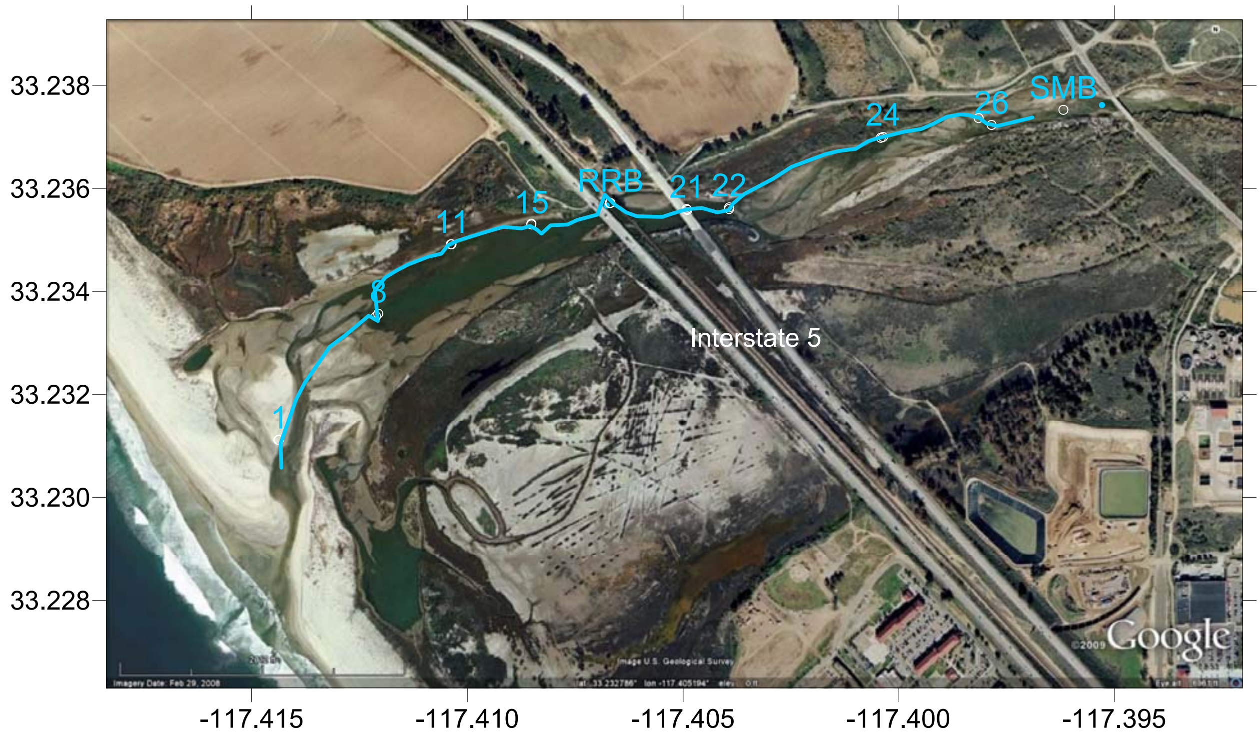


Figure 6. Spatial mapping transect conducted on 10 March 2010. Discrete water samples were collected at 10 stations along the transect. RRB = Railroad Bridge, SMB = Stuart Mesa Bridge.

Table 4. Discrete sample station locations along transects conducted during Index Period1 (left) and Index Period 2 (right). Slight variations in location were mostly a result of accessibility due to tidal variations in water depth. RRB = Railroad Bridge, SMB = Stuart Mesa Bridge.

Index 1

Station	Longitude (Degrees West)	Latitude (Degrees North)
1	117.414367	33.231117
8	117.412067	33.233567
11	117.410367	33.234917
15	117.408517	33.235300
RRB	117.406683	33.235717
21	117.404917	33.235600
22	117.403933	33.235633
24	117.400367	33.237000
26	117.397850	33.237233
SMB	117.396185	33.237527

Index 2

Station	Longitude (Degrees West)	Latitude (Degrees North)
1	117.413967	33.231150
8	117.412117	33.233667
11	117.410383	33.234017
15	117.408550	33.234833
RRB	117.406417	33.235467
21	117.404883	33.235567
22	117.404300	33.235450
24	117.397750	33.237250
26	117.396167	33.237583
SMB	117.395083	33.237717

Figure 7. Macroalgae transects from 17 March 2010 (Index Period 1). Three separate 50-m transects were sampled at marked locations. The transect lengths were reduced to 10 m and moved slightly to accommodate access during the 9 October 2010 survey (Index Period 2). Transect start shown by ◉. Transect end shown by ◉.

Table 5. Start and end of transect locations for macroalgae surveys. T3 could not be sampled because water levels were too high after the lagoon mouth had closed.

		INDEX 1		INDEX 2	
Transect		Latitude (Degrees N)	Longitude (Degrees W)	Latitude (Degrees N)	Longitude (Degrees W)
T1	Start	33.237861	117.396339	33.237910	117.396400
	End	33.237801	117.396888	33.237900	117.396510
T2	Start	33.235465	117.408174	33.235560	117.407910
	End	33.235420	117.408695	33.235540	117.408020
T3	Start	33.234173	117.412498	Not collected (water levels too high after mouth closed)	
	End	33.234023	117.412986		

Figure 8. Example photos of quadrant placement. The left photo from Index Period 1 shows placement of the quadrat and delineator on top of a sediment surface that had no macroalgae present. The right photo, taken during Index Period 2, shows placement of a quadrat above floating macroalgae prior to placing the delineator.

3. RESULTS

3.1 LOWER LAGOON LONG-TERM WATER QUALITY MONITORING

The monitoring period at the lower lagoon fixed-station began at 10 a.m. on 3 February 2010 and ended at10:45 a.m. on 8 February 2011, or 370 days and 45 minutes. This would have resulted in a maximum of 35,523 measurements collected at 15-min intervals (Table 6). However, as stated earlier, two time periods could not be monitored; during the month-long period (30 days, 2 hours) of bridge berm construction and during the nearly 2-week period (12 days, 17 hours) of excessive storm runoff. These two periods of time reduced the maximum number of measurements possible to 31,415. The instrument was removed periodically for calibration and to perform spatial mapping which resulted in some data gaps totaling approximately six days. Taking into account these periods, the maximum number of observations possible during the time period was 30,839 over 322 days. The complete dataset is provided in Appendix B and on an accompanying CD as a Microsoft Excel® spreadsheet.

3.1.1 Data Acquisition Summary

A summary of the number of measurements collected for each parameter is shown in Table 7. The real-time data acquisition completeness goal for the project, like that developed by SCCWRP (SCCWRP, 2007), was 90%. The summary shows that this was met for all parameters except depth. The maximum number of data values collected (30,528) was for temperature, representing a 99.0% successful data acquisition rate (relative to 30,839). The least number of measurements collected (27,522) was for depth values, representing an 89.2% successful data acquisition rate. The remaining variables had successful collection rates between 93.5 and 97.9%. The dataset containing complete concurrent temperature, salinity, and dissolved oxygen data was 29,570 records (95.6% completion). Of these records, 7573 or 26% of the measurements were collected when the lagoon mouth was closed.

The depth data collection rate of 89.2% was below the 90% data completeness objective developed for the Lagoon Investigative Order by SCCWRP (SCCWRP, 2007; CDM, 2007). The main loss of depth data collection (3008 records) occurred between 4 April 2010 and 6 May 2010 as a result of a depth sensor failure. It was decided (with MCBCP staff concurrence) that it was more valuable to continue collection of the key parameters, dissolved oxygen, temperature, and salinity until it could be arranged to obtain and install a new sensor from the manufacturer. The addition of these records would have resulted in a successful data acquisition rate of 99%. All other water quality parameter data exceeded the completeness objective. Loss of the depth data is not considered critical to the modeling and can be accurately estimated from the data collected before and after the sensor failure and using the USGS gage data if necessary.

A graphical review of data quality was made during each weekly or monthly calibration check, though daily Web-based monitoring was used to qualitatively evaluate the data and to identify if any of the data were clearly compromised. Occasional data quality issues arose for one or more measurement parameters, typically accounting for missing or erroneous data including sensor failures, sensor fouling, and sensors coming out of the water. A graphical review of the entire dataset was conducted at the completion of monitoring to identify and remove questionable data. The largest group of data records that were removed from the dataset was 786 dissolved oxygen values that showed a reduced sensor response as a result of heavy fouling (Figure 9) during the peak algal growth period for the year. This occurred during the week of 24 August through 1 September 2010 and again during the week of 7–14 September. There were 332 salinity data records lost when the

sensor failed during the period of 14–17 November 2010. There were very few additional data that were removed from the dataset that were not associated with a sensor failure or the fouling described above such as when the depth of the unit was insufficient to cover all the sensors in early February (47 records). This was because the sensors usually were within calibration and needed almost no adjustment over the entire monitoring period.

Table 6. Summary of monitoring period and data records collection. Dates show the full monitoring time-frame as well as periods when the instrument was out of the water during the Railroad Bridge berm construction, extreme storm conditions, and while calibrating and performing spatial mapping.

Total Monitoring Period	2/3/2010 10:00 - 2/8/2011 10:45
Days	370
Hrs	8881
15 min Intervals	**35,523**
Construction Period	6/7/2010 10:30 - 7/7/2010 12:30
Days	30
Hrs	722
15 min Intervals	**2888**
Storm Blowout Period	12/22/2010 18:00 - 01/04/2011 11:00
Days	12
Hrs	305
15 min Intervals	**1220**
Calibrations est (hrs)	144
Days	6
Hrs	144
15 min Intervals	**576**
Maximum Days Monitored	**322**
Maximum Records Possible	**30,839**

Table 7. Summary of data records acquired by parameter and percent acquired relative to maximum records possible.

Counter	Depth (cm)	Temperature (°C)	Specific Conductivity (µS/cm)	Salinity (PSU)	pH	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Data Records	27,522	30,528	30,196	30,196	29,171	29,576	29,576
% Acquired	89.2%	99.0%	97.9%	97.9%	94.6%	95.9%	95.9%

Figure 9. Pictures of fouled multiparameter probe (left) and protective mounting tube (right) on 1 September 2010. The heavy fouling led to a reduced dissolved oxygen signal. Data during this time period were removed from the dataset.

3.1.2 Summary Statistics

Summary statistics for the long-term monitoring conducted at the lower lagoon fixed station, first at the Railroad Bridge, and then at the south shore rip-rap location are shown in Table 8. These data were compared to two other long-term datasets collected in the lower lagoon. The first of these was collected in similar fashion by SCCWRP at the I5 Bridge between December 2008 and November 2009 (SCCWRP, 2010). Summary statistics for the SCCWRP data are shown in Section 3.1.7. As described earlier, discrete water samples were collected for analysis of dissolved oxygen using a standard Winkler titration method. This was done as another check on measurement accuracy of the real-time optical sensors used throughout the project. A comparison was made between the sensor value measured at the time of the sample collection and the titration value of the Winkler analysis. Comparisons made for the two sensors used in the project are show in Table 9.The second dataset was collected by the USGS at their gauge location just south of the Railroad Bridge and posted on their website (USGS Gage Location 11046050: http://waterdata.usgs.gov/nwis/ nwisman /?site _no =1 1046050 &agency_cd=USGS). Summary statistics for the USGS data are shown in Table 10. The USGS data encompass the same time period as the data collected in this study, but were only available as daily minimum and maximums. The average values identified in the table were calculated from the average of the daily minimum and maximum and as such are not true daily averages but are provided for comparison purposes only. In addition, the USGS depth values describe actual surface water elevation (gage height) rather sensor depth.

In general, the summary statistics compare well with differences typically less than 10%. This suggests relatively consistent conditions in the lower lagoon between years as well relatively consistent data collected by independent systems during the same year. Differences between years for temperature and salinity were in the 20 to 25% range. Most of the differences in the datasets can be attributed to natural inter-annual variations in solar insolation or runoff amounts, though sensor placement and missing periods of data in datasets also played a role.

Visual inspection (Figure 10 through Figure 15) and a Fast Fourier Transform analysis were conducted on the full datasets. The analysis showed consistent trends in some standard water quality parameters as well as some distinct differences between years and between independent measures made during the same year. Water depth in the lagoon was primarily driven by semidiurnal tidal exchange with the Ocean, though rain events and the mouth closure clearly influenced the level as

well. The tidal signal is clearly shown in Figure 10 for the two different years. The tidal amplitude averaged 54 cm in 2010–2011 and 63 cm in 2008–2009. All three datasets (SCCWRP, USGS, and SSC Pacific) showed decreasing amplitude in water level from ~100 cm in winter and spring to ~50 cm in summer and fall. The reduced amplitude was a result of natural build-up of the beach berm at the ocean mouth, which in 2010 (1 October through 20 December) eventually built up high enough to shut off exchange entirely with the lagoon. During that period, the daily fluctuations in water level were less than ~5 cm. Water depth overall in the lagoon slowly increased about 30 cm during this time only as a result of freshwater inflow. About 20 cm of the gain in water level occurred after a 2- to 3-inch rain event during 19-20 October 2010 (NOAA National Weather Service Data Archives for Vista, Oceanside, Carlsbad Airport, Fallbrook, Temecula, at http://www.wrh.noaa.gov/sgx/obs/rtp/rtpmap. php?wfo=sgx). Tidal flow was restored after the mouth was reopened during the very large intense rainfall (6.7 inches at Oceanside Airport) that occurred 16–22 December 2010.

3.1.3 Temperature

Lagoon water temperature followed a very consistent daily and annual signal in the two different year datasets (Figure 11). Lagoon water temperatures in the 2010 SSC Pacific dataset ranged from 9.6 to 29.4 ºC and averaged 18.6 ºC. Daily fluctuations averaged 4.3 ºC with a maximum of 11.3 ºC. The 2008–2009 SCCWRP dataset was a bit higher overall ranging from 7.7 to 29.6 ºC and averaged 19.8 ºC, though the average daily fluctuation of 4.0 ºC was nearly identical. Water temperatures were driven primarily by diurnal and seasonal changes in solar insolation/heating along with the semidiurnal tidal exchange (Figure 11). Temperatures were commonly highest at low tide, a result of having a fixed sensor that was effectively measuring water closer to the surface during lower water levels (Figure 12).

It is clear from Figure 12 that the daily fluctuation of temperature was more pronounced in summer as a result of solar heating of the shallow lower lagoon and river water relative to the incoming ocean waters. The lack of tidal exchange during the end of the October index 2 period showed that diurnal affects were minimal, with changes in water temperature of about 0.5 ºC.

Lagoon waters showed a consistent warming through the summer, peaking in July and August and cooling into November through February (Figure 12). The USGS data for 2010 showed that temperatures decreased to as low as 5 ºC during the five days of heavy rains in December (Figure 11). This temperature is the lowest recorded by the USGS over the past 15 years and seems suspect though a review of the past 15 years of data show a few other instances of when temperatures dropped down below 6 ºC, likely during times of intense cold winter storms. There were no corroborating data during that timeframe because the SSC Pacific sensor had been knocked out of the water.

3.1.4 Conductivity

Lagoon-water-specific conductivity showed large semidiurnal fluctuations as a result of mixing of freshwater inflow from the river and tidal exchange with the ocean (Figure 13). Values ranged from virtually zero (26 µS/cm) to over 57,000 µS/cm. Comparable salinities ranged from 0 to 39.0 psu. Daily variations of over 51,00 µS/cm in winter (February) decreased into the summer as a result of reduced tidal exchange and less freshwater inflow. Virtually no variation existed during the mouth closure period in October. The three datasets were in generally good agreement, though the SCCWRP and USGS datasets appeared to have a small (2,000 µS/cm) positive and negative offset, respective to the SSC Pacific dataset. Specific conductivity values, normalized to 25ºC, allows for direct comparison between datasets.

3.1.5 pH

The pH of lagoon waters varied between 7.2 and 9.2 and averaged 8.2 throughout the 2010–2011 timeframe (Figure 14). Similar to water temperature values, daily variations were primarily diurnal in nature, being tied to changes in carbon dioxide use or generation by phytoplankton during respiration (dark) or photosynthesis (light). Daily fluctuations in pH were highest in winter and spring (~0.5) and decreased through summer (~0.25). The SSC Pacific and SCCWRP datasets were fairly consistent over the two-year time span with exactly the same average values though the SCCWRP dataset commonly was higher by about 0.3 pH units. For the most part, the daily minimum/maximum USGS gage data bracket the SSC Pacific data well but was there were clearly occasions, particularly October through December, when pH values were exceptionally high, suggesting that the unit was out of calibration.

3.1.6 Oxygen

Dissolved oxygen values in the lagoon varied between 0 and 21 mg/L and averaged 8.2 mg/L (Figure 15). The data showed daily variations up to nearly 20 mg/L. The daily variations were typically smallest in the late fall and winter and maximum in the spring. The spring maximum may be an artifact of not having early summer for comparison, but the increase was related to increasing seasonal solar insolation and temperature and resultant algal production. The lower overall values of dissolved oxygen and reduced variations in late fall likely reflect the low-flow conditions during the mouth closure.

The combination of low flow and relocating the sensor to the Riprap site played a small role in observing lower and near-zero dissolved oxygen values during part of October. Under normal flow conditions, the site was just as representative of the lower lagoon as the original Railroad Bridge site. Any differences were minor and were a result of the spatial variation. However, under the low-flow conditions the stagnant nature of the water along the shoreline (vice mid-stream) led to some localized vertical stratification and the lower oxygen levels. During that time, the sensor was determined to be responding correctly based on calibration checks and by changing location and depth. So while the readings were correct, they were lower than what was observed further out from the shoreline. A comparison of the data collected at the RRB and Riprap site with the USGS dataset during other times indicates that the two sites did provide comparable results during normal flow conditions.

In general, the year-to-year variations (compared to SCCWRP) in daily and seasonal values were reasonably consistent, though minimum daily concentrations were shifted slightly in time to summer and fall vice fall and winter. The only exception was the January–February 2009 timeframe in which the SCCWRP data showed lower overall values and much larger daily swings in the dataset. A comparison to the USGS dataset collected during that same timeframe (not shown) confirms that the SCCWRP oxygen data during that timeframe were likely biased low by as much as 4 mg/L. Another minor issue for these comparisons might be related to whether or not the SCCWRP sensor data was affected by the salinity effect that was corrected for the SSC Pacific sensor (See QA/QC section).

There were also several periods when the USGS data appeared to be inaccurate relative to the SSC Pacific dataset. The sensor appeared to be inaccurately too high during the late July through late September and again in the late October through late November timeframes when peak USGS values where commonly as much as 9 mg/L higher than the SSC Pacific dataset. In some instances, the USGS sensor appeared to have reached an upper sensor limit of 20 mg/L. There were also two periods when the USGS sensor appeared to be inaccurately low, reading near zero for both minimum and maximum values during the October Index Period 2 period of lagoon mouth closure and then in late November through early January when minimum values were all zero.

Dissolved oxygen variations were driven primarily by diurnal changes associated with photosynthetic generation during daylight hours and respiration during nighttime hours. Dissolved oxygen values were lowest in the early morning (~5 to 7 a.m.) and maximum in the late afternoon (~4 to 6 p.m.). The timing of minimum/maximum values shifted slightly through the year as a result of longer daylight hours in summer (Figure 18). These data indicate the main source of variation was algal production during daylight hours and respiration at night. The amount of oxygen dissolved in the water, was on average, 97% of amount expected to occur based on equilibration with the atmosphere. This percentage ranged from 0% to as much as 270%, showing the role of the biological processes versus temperature effects in controlling the levels.

Currently, the water quality objectives for dissolved oxygen levels in California surface waters *states:*

> "*Dissolved oxygen levels shall not be less than 5.0 mg/l in inland surface waters with designated MAR or WARM beneficial uses or lessthan 6.0 mg/l in waters with designated COLD beneficial uses. The annual mean dissolved oxygen concentration shall not be less than 7 mg/l more than 10% of the time (*SDRWQCB, 1994 amended in 2007*).*"

Though there are current efforts by the SDRWQCB, the State Water Resources Control Board, the EPA, and Santa Margarita stakeholders to re-evaluate oxygen and nutrient objectives, the data were evaluated against the current requirement. The annual average value for the lower lagoon of 8.17 mg/L meets the criterion though values fell below the 5.0 mg/L limit 15.5% of the time (Figure 17). These results compare to SCCWRP's dataset that had 22.1% of the data falling below the 5 mg/L objective. About 1.5% of the SSC Pacific dissolved oxygen values were zero. Nearly all of these data occurred during the October Index 2 period when the lagoon mouth was closed off and when the sensor was at the Riprap site, which as described earlier, was particularly affected by the low flow and localized stratification. The issue of sensor placement, spatial variability, and sensor accuracy needs to be accounted for when identifying future water quality objectives.

Table 8. Summary statistics for long-term monitoring data collected at the lower lagoon station by SSC Pacific. As described previously, the station was at first located at the Railroad Bridge and then moved in July 2011 to the south shore Riprap area after bridge construction began.

Statistic	Depth (cm)	Temperature (°C)	Specific Conductivity (µS/cm)	Salinity (PSU)	pH	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Min	0.00	9.62	26.4	0.01	7.19	0.00	0.00
Max	187.1	29.38	57,334	39.00	9.14	21.1	272
Stdev	28.2	4.04	17,982	12.25	0.33	3.09	36.5
Average	**59.2**	**18.64**	**32,265**	**21.07**	**8.20**	**8.17**	**96.9**

3.1.7 Comparison between Sensors and Winkler titrations

As described earlier, discrete water samples were collected for analysis of dissolved oxygen using a standard Winkler titration method. This was done as another check on measurement accuracy of the real-time optical sensors used throughout the project. A comparison was made between the sensor value measured at the time of sample collection and the titration value of the Winkler analysis. Comparisons made for the two sensors used in the project are shown in Figure 18.

Table 9. Summary statistics for long-term monitoring data in the lower lagoon (I-5 Bridge) by SCCWRP (SCCWRP, 2010) conducted between December 2008 and January 2009. Specific conductivity values were not available.

Statistic	Depth (cm)	Temperature (°C)	Specific Conductivity (µS/cm)	Salinity (PSU)	pH	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Min	0.00	7.72	23.0	0.01	7.14	0.06	0.60
Max	153.1	29.65	52,669	34.66	9.05	20.4	276
Stdev	26.1	4.79	15,082	10.15	0.29	3.06	42.2
Average	**54.5**	**19.80**	**42,316**	**27.54**	**8.22**	**7.63**	**98.6**

Table 10. Summary statistics based on 2010 USGS daily minimum/maximum values for a site in the lower lagoon south of the Railroad Bridge (USGS ro 11046050, SANTA MARGARITA R A MO NR OCEANSIDE CA). Average values were calculated as the average of daily minimum and daily maximum. Specific conductivity, salinity, and oxygen saturation values were unavailable.

Statistic	Depth (cm)	Temperature (°C)	Specific Conductivity (µS/cm)	Salinity (PSU)	pH	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Min	77.7	7.80	0.6	na	7.50	0.20	na
Max	245.1	29.80	50,600	na	9.70	19.50	na
Average	**149.3**	**19.92**	**34,961**	**na**	**8.46**	**8.25**	**na**

The sensor measurements were in generally good agreement with the Winkler titrations. On average, concentrations measured by both methods were within 1.2 ±1.2 mg/L (n = 45) for the Troll and within 2.1 ±1.2 mg/L (n=12) for the Hach. The data comparisons had reasonably good correlations with coefficients of 0.70 and 0.62, respectively, for each dataset. However, some results clearly showed differences of up to 4.5 mg/L. Though care was taken to collect samples consistently, it is believed that the observed differences were attributed to variations in sampling procedures, primarily in matching sample depths when there appeared to be localized stratification. Removal of a couple of data points that visually appeared to be outliers improved both regression coefficients to 0.80. These calibration checks indicate that the sensors were providing good quality data throughout the project. However, variations observed in both the calibration measurements and in data collected simultaneously from different sensors suggest that there will always be some uncertainty in the true value of dissolved oxygen measured. Accuracy of better than 1 mg/L should probably not be expected. This uncertainty is particularly important when hard limits are placed as water quality objectives.

3.2 INDEX PERIOD MONITORING DATA

Index period sampling was conducted 10 March through 8 April and again 20 September through 19 October 2010. During these two periods, fixed-station monitoring, discrete water sampling, spatial mapping, and benthic algae surveys were conducted in the lower and upper lagoon. The lower lagoon site was the Railroad Bridge during Index Period 1and was the Riprap site during Index Period 2. The upper lagoon site was the Stuart Mesa Bridge for both periods. Data were compared between the lower and upper lagoon fixed sites during each index period, as well as at each site for both index periods.

Table 11 summarizes the observations made at the two sites during the two index periods. The total number of 15-minute data points collected at each sensor location and both periods ranged between 2609 and 3311. These datasets had a 100% data acquisition rate outside of having to pull the sensors out during calibration checks. The Lower Lagoon Index 1 dataset was slightly larger than the other datasets as the collection time was extended an extra week to overlap full data collection in the upper lagoon when a battery pack failure delayed the start of upper lagoon data acquisition.

Generally, water quality was consistent throughout the lagoon during each index period. Data collected in the upper lagoon mirrored the lower lagoon. Both sites experienced the same semidiurnal tidal or diurnal fluctuations, or not, when the lagoon mouth was closed. The fluctuations at both sites were synchronized throughout the two index periods, indicating that the predominant tidal and algal processes observed in the lower lagoon were also occurring in the upper lagoon. Only the magnitude of these processes resulted in the observed differences between the upper and lower lagoon values.

Water quality data were far greater between index periods at each site than was observed between sites during the same index period. These seasonal differences, a result of the changes in tidal flow, freshwater inflow, and differential solar heating already discussed for the lower lagoon, were clearly observed in the upper lagoon as well.

Daily depth variations in the upper lagoon ranged between 50 and 80% of those in the lower lagoon during Index 1 (Figure 19 top). The differences were smallest during the larger magnitude Spring tide and maximum during the smaller magnitude Neap tides. There was very little difference in depth fluctuations throughout the lagoon during most of the second index period as a result of the mouth closure October through mid-December. A comparison of the top and bottom plots in Figure 19 show the reduced tidal effect at both sites as a result of the mouth closure.

Temperatures in the lower lagoon were usually a few degrees warmer than the upper lagoon throughout most of the first index period and a few degrees cooler in the second index period (Figure 11). These results are consistent with an expectation of differential solar heating of the shallow river water versus ocean water during the two time periods.

Specific conductivity values were overall lower in the upper lagoon (Figure 21 top), a result of freshwater inflow of the river at the head of the lagoon and exchange with ocean water at the mouth. Mixing was complete during the Spring tide in the third week of Index Period 1 as values were very nearly the same for both sites. The tide reached the Stuart Mesa Bridge site even during the early part of Index Period 2 when the tidal signal was muted (Figure 21 bottom), ostennsibly as a result of Figure 21 bottom), ostennsibly as a result of a higher berm at the mouth.

Dissolved oxygen was consistent throughout the lagoon during the first index period though values were generally a bit higher in the lower lagoon during the second index period (Figure 22). The diurnal signal was also consistent at both sites for both periods. One exception was the period between 16 and 19 October when the sensor in the lower lagoon was reading zero with little to no flow at the Riprap site.

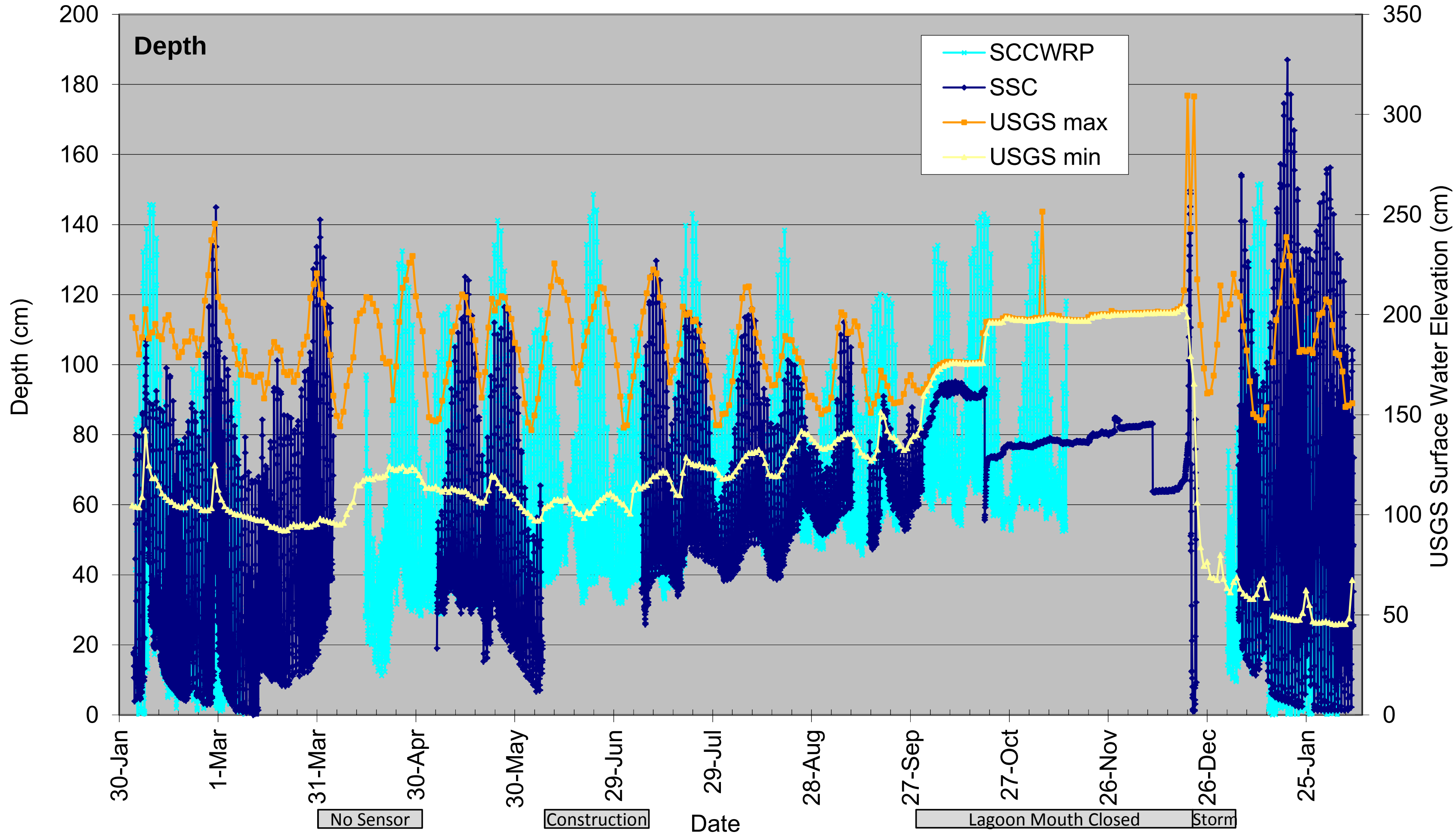


Figure 10. Sensor depth (cm) hourly data collected in the lower lagoon in this study (SSC Pacific) along with daily minimum and maximum gage height data collected by the USGS for the same time period and overlain by 2008–2009 sensor depth dataset collected by SCCWRP (2010). Differences in the absolute values were dependent on where the sensor was placed in the water column.

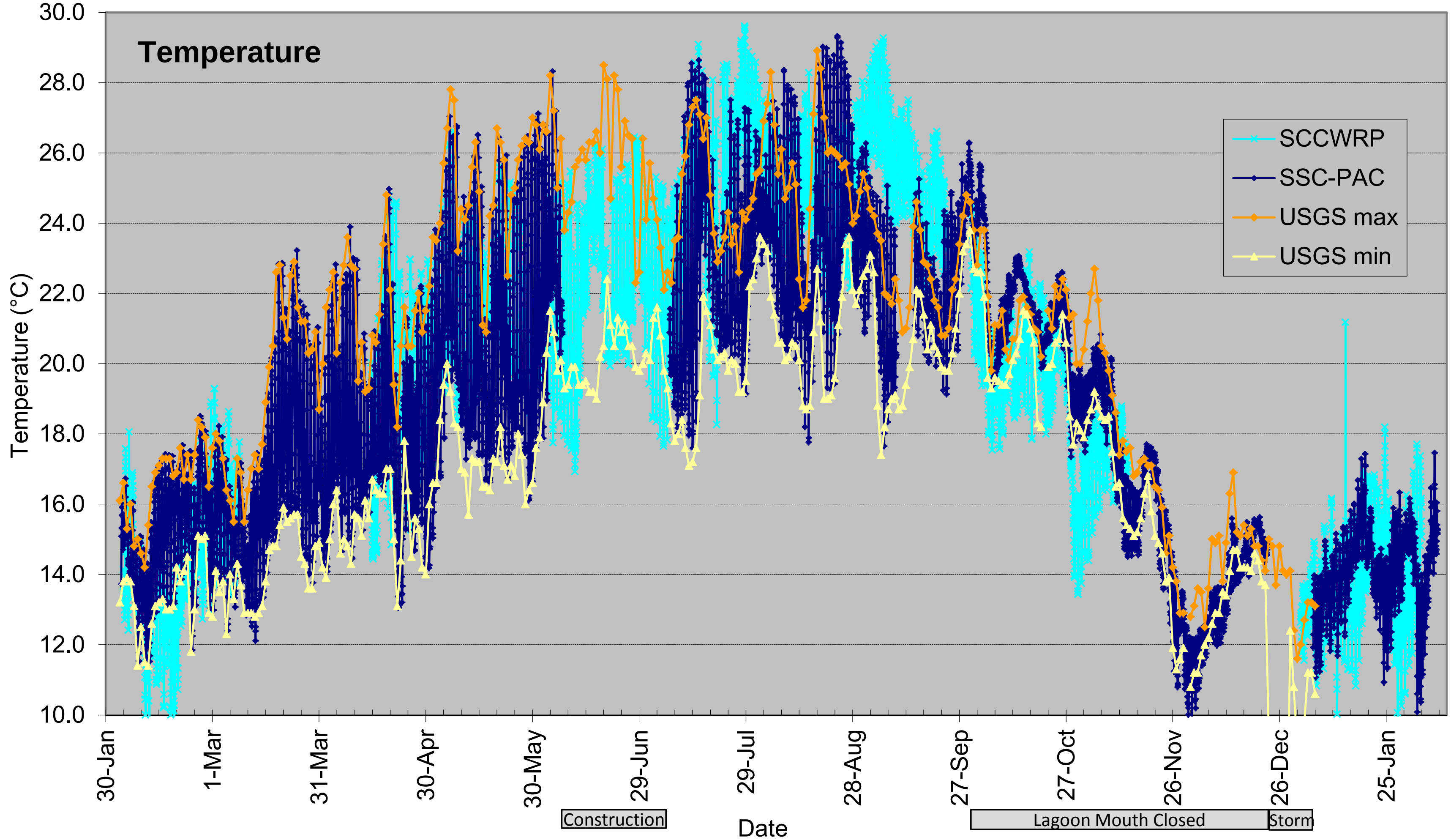


Figure 11. Temperature (°C) hourly data collected in the lower lagoon in this study (SSC Pacific) along with daily minimum and maximum data collected by the USGS for the same time period and overlain by 2008–2009 dataset collected by SCCWRP (2010).

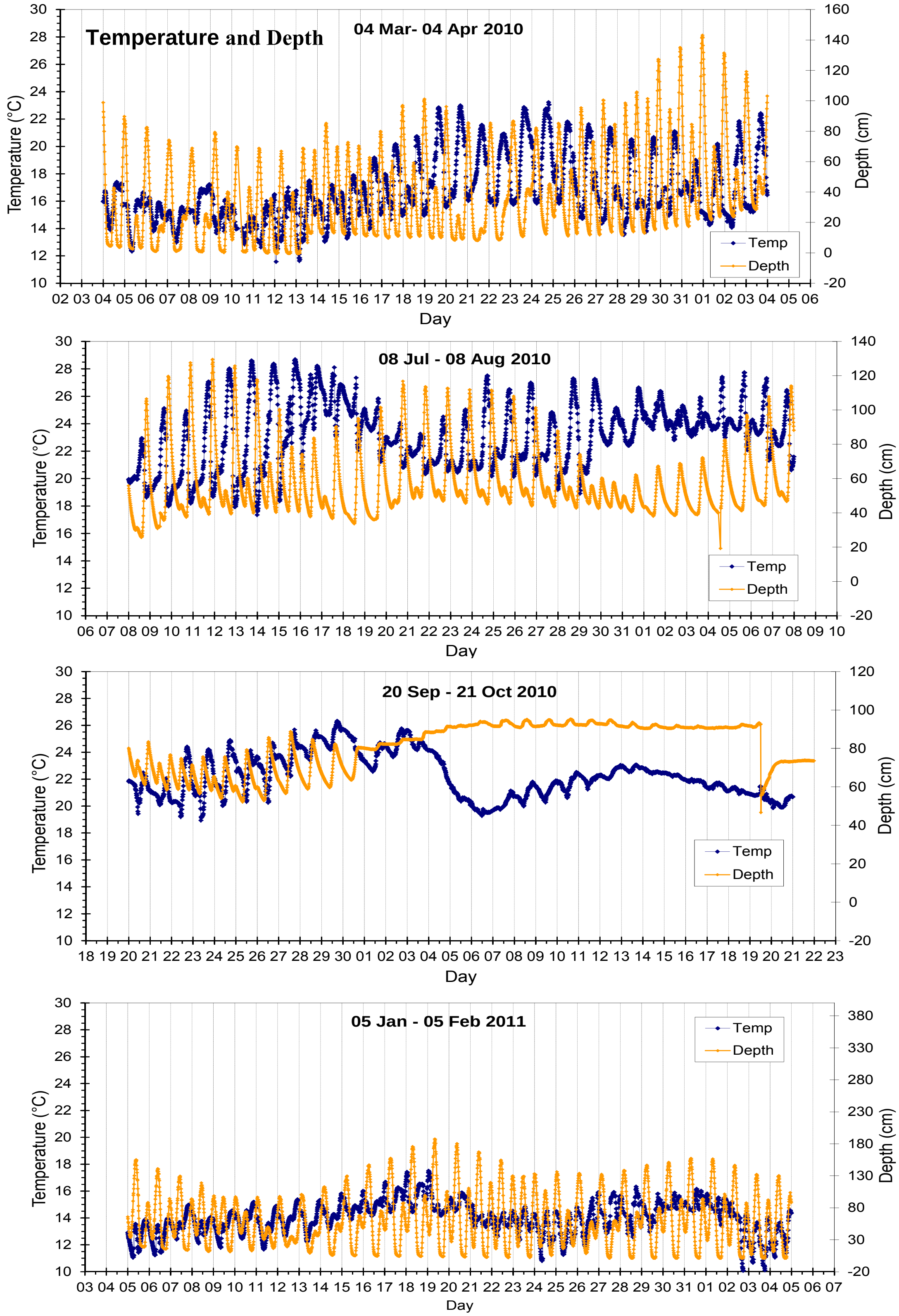


Figure 12. Lower Lagoon water temperatures (ºC) measured at 15-minute intervals during four seasonal 30-day periods. Grid lines are at midnight for each day. All plots use the same temperature scale.

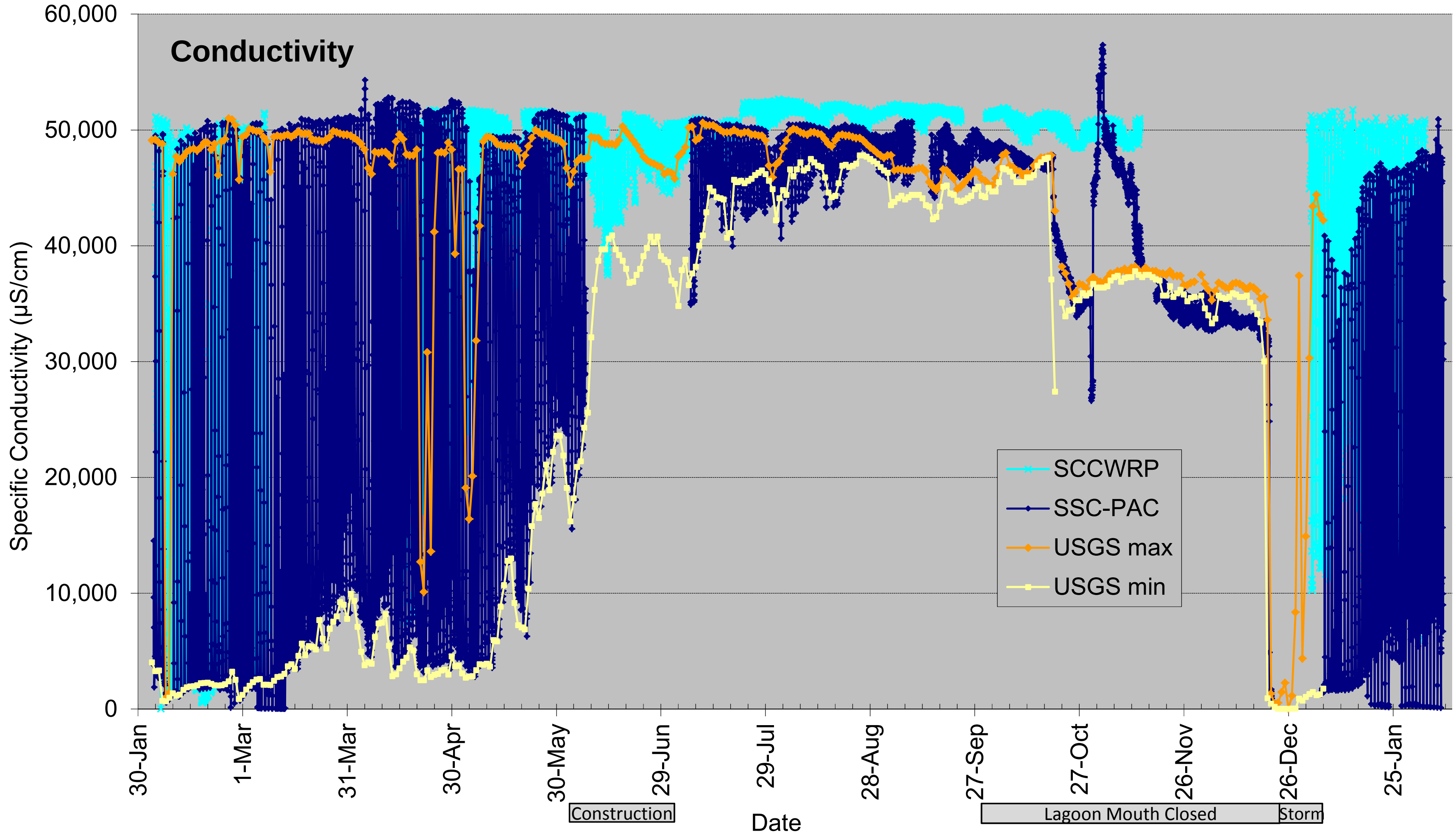


Figure 13. Specific conductivity (µS/cm) hourly data collected in the lower lagoon in this study (SSC Pacific) along with daily minimum and maximum data collected by the USGS for the same time period and overlain by 2008–2009 dataset collected by SCCWRP (2010).

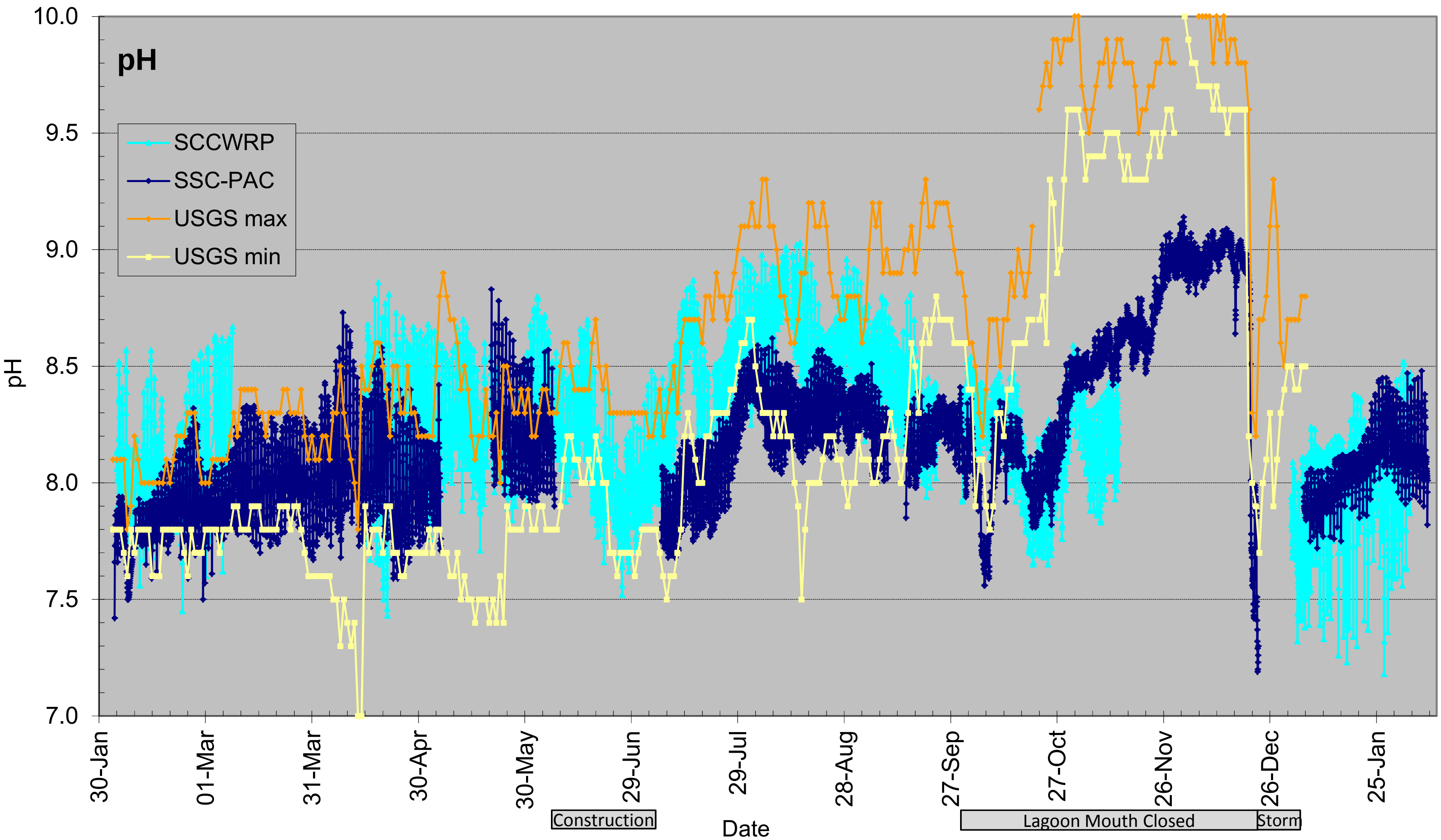


Figure 14. Hourly pH data collected in the lower lagoon in this study (SSC Pacific) along with daily minimum and maximum data collected by the USGS for the same time period and overlain by 2008–2009 dataset collected by SCCWRP (2010).

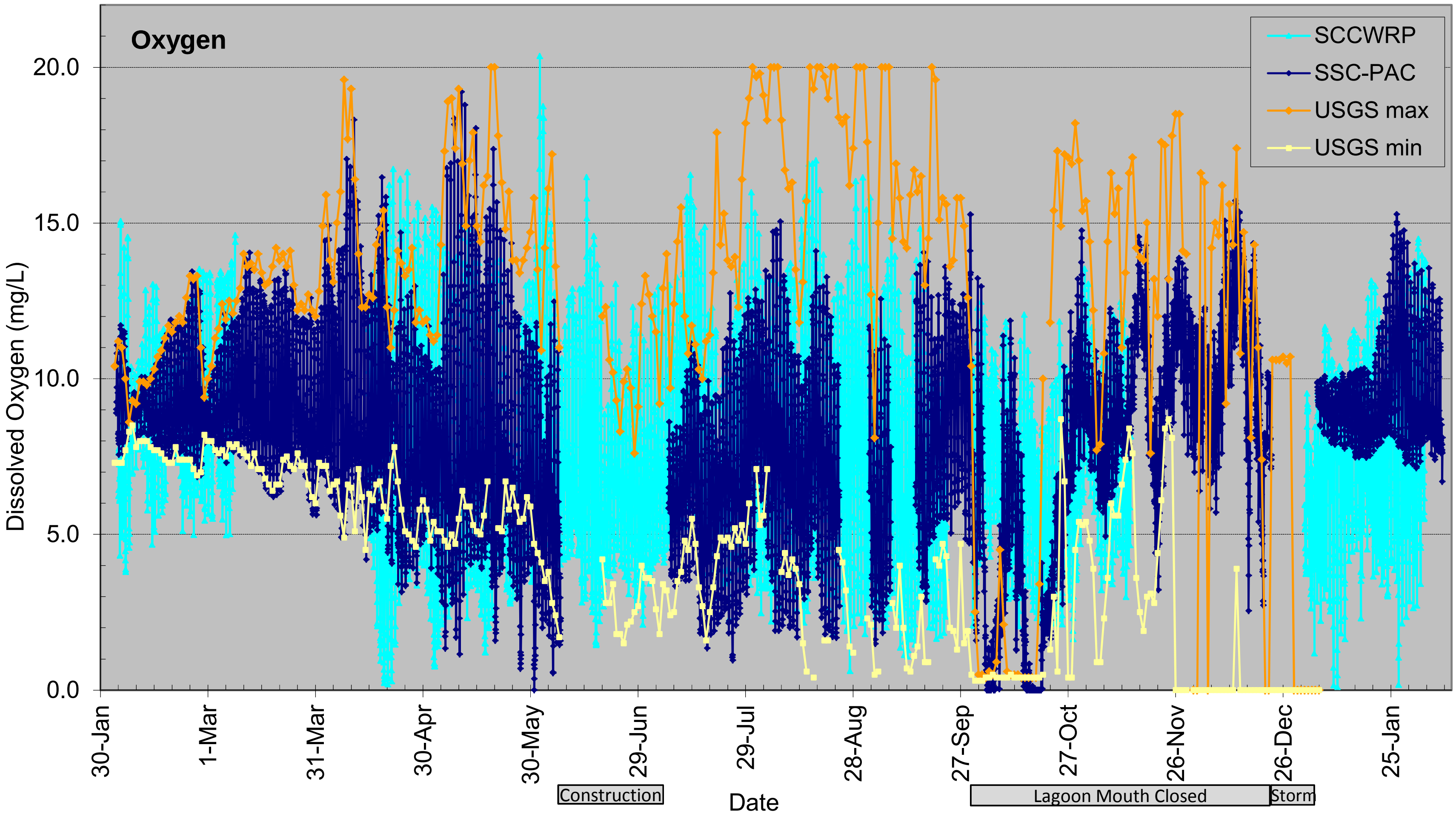


Figure 15. Hourly dissolved oxygen data collected in the lower lagoon in this study (SSC San Diego [now SSC Pacific], 2007) along with daily minimum and maximum data collected by the USGS for the same time period and overlain by 2008–2009 dataset collected by SCCWRP (2010).

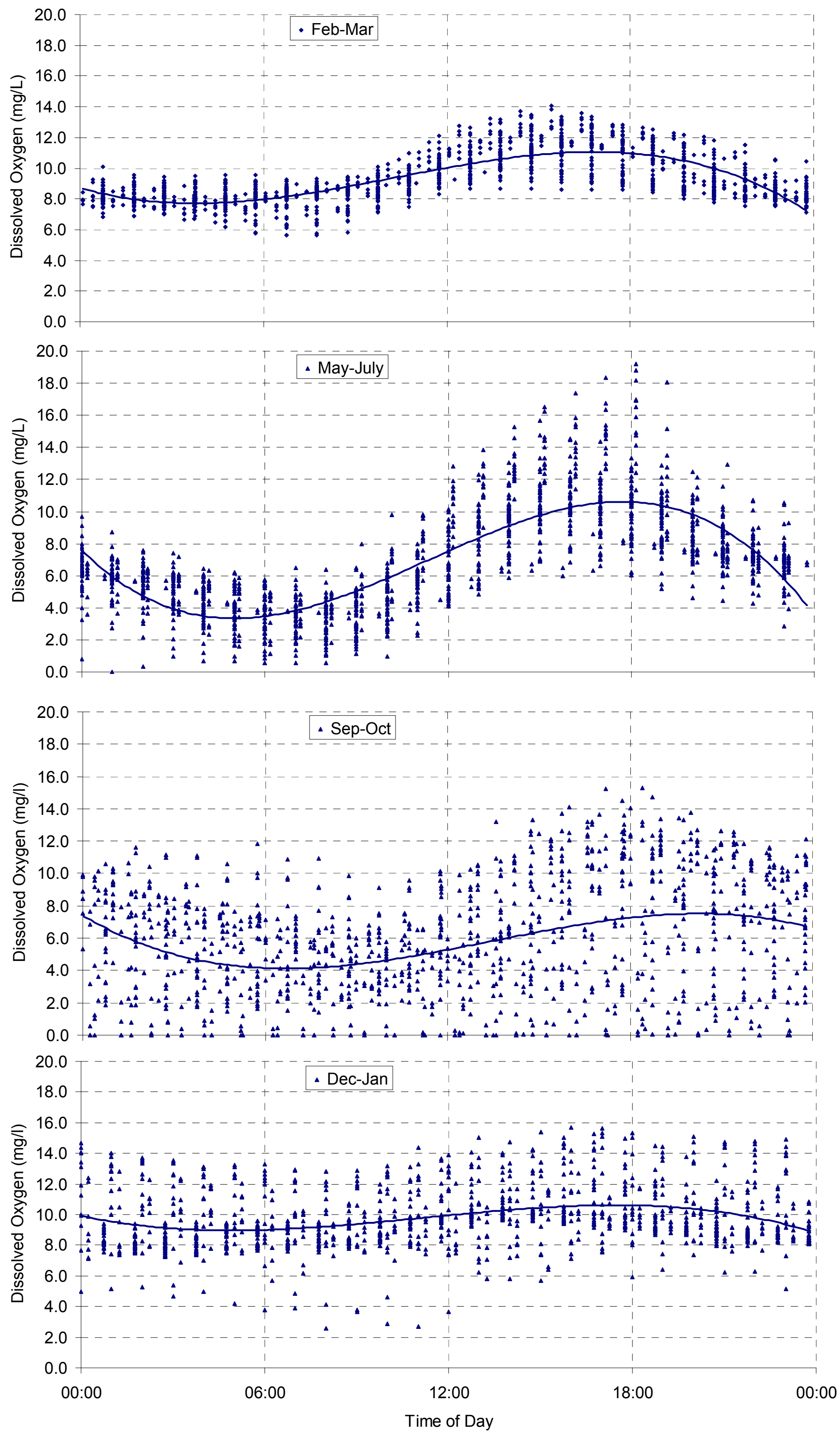


Figure 16. Lower lagoon dissolved oxygen concentrations (mg/L) measured as a function of hours of the day during four seasonal periods. All plots use the same scales.

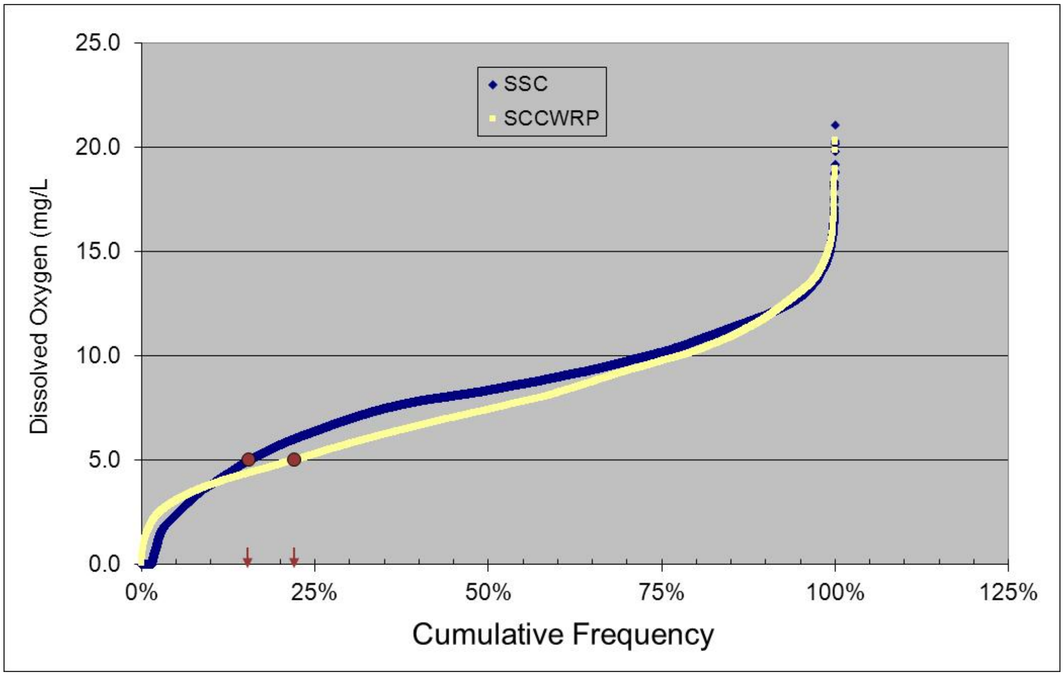


Figure 17. Cumulative frequency plot of lower lagoon dissolved oxygen concentrations measured over the 1-year monitoring period. Values less than the 5 mg/L of the water quality objective made up 15.5 and 22.1% of the SSC Pacific and SCCWRP datasets, respectively.

3.3 INDEX PERIOD SPATIAL MAPPING DATA

One spatial mapping survey was conducted each index period to evaluate how water quality varied throughout the lagoon. The transects were planned to cover a wide area of the lagoon by zigzagging toward each shoreline while moving along the longitudinal axis. However, the shallow nature of most of the lagoon forced the transects to be conducted within a narrow longitudinal path where the water was at least 1-foot deep to allow a small boat to transit. This limited the spatial coverage to the mostly longitudinal path shown in Figure 6. The 10 March 2010 survey was conducted during an ebb tide while the 12 October 2010 survey was conducted during what would have been a flood tide except that the mouth was closed.

The spatial mapping results are shown graphically for Index Period 1 and Index Period 2 in Figure 23 and Figure 24 and Table 24, respectively. The data from both time periods are plotted on similar scales, with the x-axis based on time though reversed so the graph appears to be west (left) to east (right). The Index 2 survey was paused about midway for over 1.5 hours to meet with MCBCP staff on shore. Just before moving into shore the conductivity signal jumped ~ 9,000 µs/cm possibly when tangled up with some floating algal. The signal jumped back to its previous level after about 8 minutes (48 data points). The 48 data points (6% of the survey) were removed from the data presentation because the large observed change were considered suspect. However, these data were left in the final data delivery file. Some additional editing of the data files was conducted to remove spurious data that occurred such as when a sensor was pulled from the water to remove algae off the sensor cage. The complete dataset is included in Appendix B on the accompanying CD.

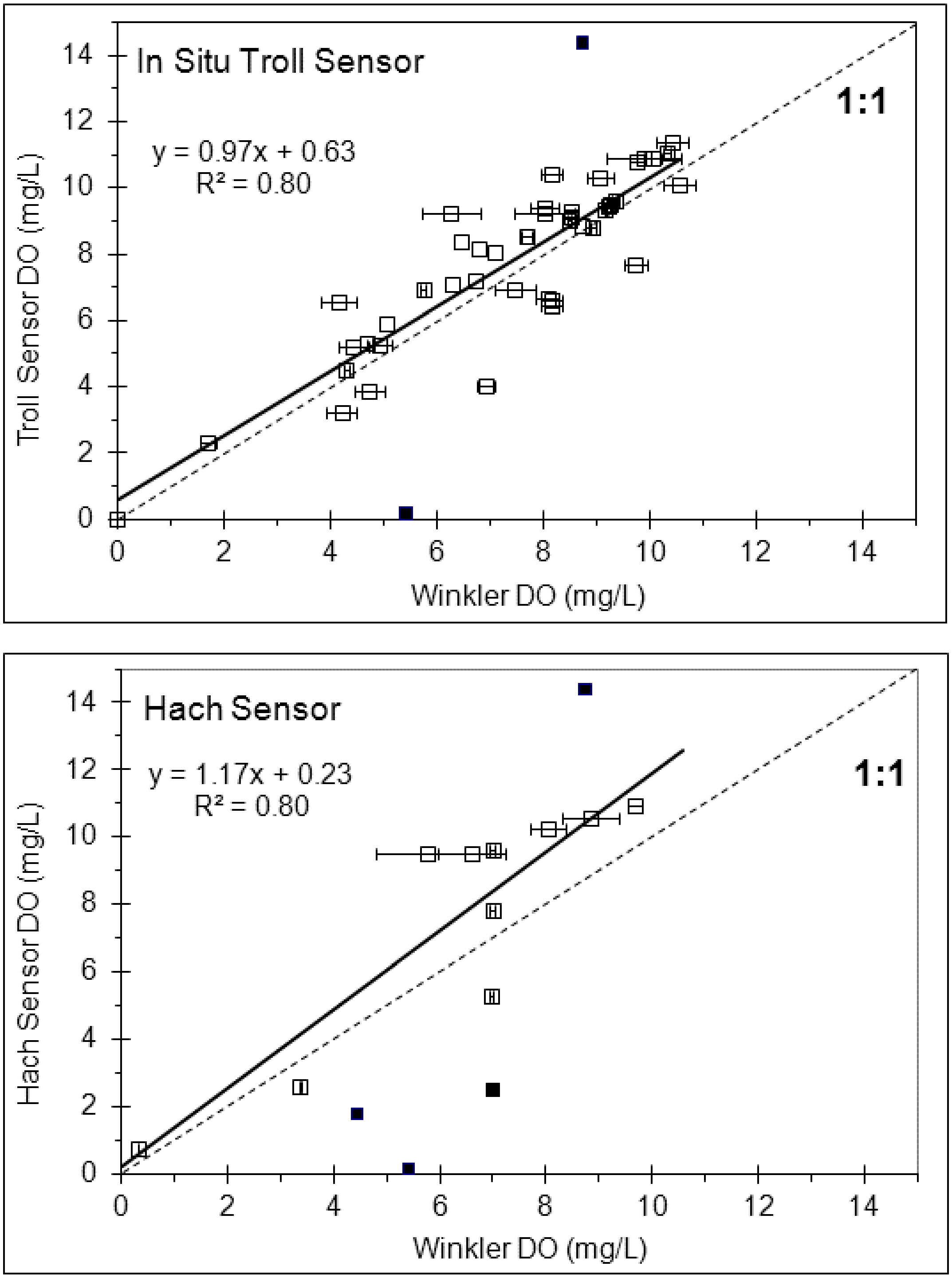


Figure 18. Comparison of dissolved oxygen concentrations measured by real-time sensor Troll (top) and Hach (bottom) sensors with values measured by Winkler titration of discrete water samples. Regression lines excluded data shown as closed squares.

Table 11. Summary statistics for fixed-station sensor data collection at the lower and upper lagoon sites during Index Period 1 (March/April 2010) and Index Period 2 (September/October 2010).

Index 1 Lower	Depth (cm)	Temperature (°C)	Specific Conductivity (µS/cm)	Salinity (PSU)	pH	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)
Count	2933	3311	3311	3311	3311	3311	3311
Min	0	11.57	37	0.02	7.67	4.45	54.3
Max	143	24.08	54,313	36.23	8.73	18.17	230.3
Ave	39	17.03	20,011	12.59	8.01	9.43	105.1
Index 2 Lower							
Count	2609	2609	2609	2609	2609	2609	2609
Min	47	18.94	34,255	22.09	7.56	0.00	0.0
Max	95	26.33	50,120	33.91	8.43	15.71	236.4
Ave	82	22.25	47,763	32.10	8.11	5.19	72.8
Index 1 Upper	**Depth (cm)**	**Temperature (°C)**	**Specific Conductivity (µS/cm)**	**Salinity (PSU)**	**pH**	**Dissolved Oxygen (mg/L)**	**Dissolved Oxygen (% Saturation)**
Count	2760	2760	2760	2760	na	2760	2760
Min	47	12.06	1332	0.70	na	4.62	50.4
Max	148	20.59	48,897	32.01	na	15.38	168.5
Ave	69	17.26	9380	5.67	na	9.27	99.2
Index 2 Upper							
Count	2760	2760	2760	2760	na	2760	2760
Min	30	19.30	34,550	21.71	na	0.01	0.1
Max	77	28.05	46,066	29.94	na	10.51	155.6
Ave	55	23.44	41,711	27.00	na	4.70	65.0

The data, as discussed earlier, suggest that the differences from the Lower to the upper lagoon were smaller than differences observed seasonally. The March Index 1 period plot shows decreasing temperature and conductivity and pretty flat levels of pH and dissolved oxygen moving from the ocean inland to the Stuart Mesa Bridge. The changes were relatively small except for conductivity, which changed from a saltwater to freshwater regime just west of the Railroad Bridge. The main signal of freshwater was observed westward to about station 24. These results were consistent with the upper vs. lower lagoon fixed station data collected during the period. The spatial data were relatively consistent with observations made during similar transects and tidal conditions in March 2007 (SSC San Diego {now SSC Pacific], 2007) and March 2008 (CDM, 2009). In all three cases conductivity increased toward the ocean while pH and dissolved oxygen were relatively flat or slightly increased upstream from the ocean. The 2007 SSC PAC dataset also showed a higher degree of oxygen variability, potentially as a result of more north and south spatial coverage from a transect that was run in a zigzag fashion. While all the other parameters were consistent amongst datasets, temperature decreased upstream in the current dataset (2010) though it increased upstream in both the 2007 and 2008 datasets. The differences can be attributed to cooler weather and more rainfall near the time of sampling in 2010.

The October Index Period 2 plot shows slightly decreasing dissolved oxygen, conductivity and pH and increasing temperature from the ocean upstream toward the Stuart Mesa Bridge. The changes were relatively small for all parameters, including conductivity as a result of the lagoon mouth closure, These results were consistent with the upper vs. lower lagoon fixed station data except for the lower dissolved oxygen data that were observed at the Riprap site. At this site, the sensor was reading roughly 3 mg/L, about half the value observed further out toward the middle of the lagoon

during the transect. These data suggest, as discussed previously, that this sensor location was not representative of the lagoon at least during the timeframe of closure and low flow. The data were not consistent with observations made during a similar transect and tide stage in October 2006 (SSC, 2007). In that dataset, the lagoon mouth appeared to be open and temperatures, pH, and oxygen decreased toward the ocean while oxygen generally increased toward the ocean though was considerably more variable. The October 2006 observations were however, consistent with the CDM transect data collected in October 2008 (CDM, 2009), again when the mouth was open.

3.4 INDEX PERIODS DISCRETE WATER SAMPLE DATA

Discrete water samples were collected and analyzed for TSS, chlorophyll-*a,* and nutrients during the two index periods. These included weekly sampling at the two fixed-station sites and at eight additional stations when performing the spatial mapping surveys. The data are shown in Table 12 through Table 15 below. The data in the tables are divided up by fixed-station monitoring sites and by spatial mapping stations. For comparison purposes, the data for samples collected at the fixed-station sites during the mapping surveys are repeated in the section for the spatial mapping sites. The RRB suffix on sample names refers to the lower lagoon fixed-station site at the Railroad Bridge while SMB suffix refers to the Stuart Mesa Bridge. Even though the monitoring site in the lower lagoon was moved in October, discrete samples were still collected by the Railroad Bridge site. Grayed out cells in the tables identify values measured at the detection limit of the analysis. The complete discrete sample data results are provided in Appendix B on the accompanying CD.

Quality assurance data are shown in Table 16 and Table 17. Reproducibility of the data was in the range of 0 to 18% and averaged 3.5%. Spiked samples were measured within 6.3% of the true value and averaged 2.5%. Both sets of QA data were within the project precision goals as outlined by the Lagoon Monitoring Workplan (SCCWRP, 2007; CDM, 2007). As mentioned previously, total dissolved nitrogen and total dissolved total phosphorous were not analyzed on samples collected during the Index Period 2 sampling because of a miscommunication with the analytical laboratory. However, because Total Nitrogen was run instead, there was no loss in nitrogen speciation data. But the 50% loss in TDP data also resulted in the 50% loss of Total Particulate Phosphorous data derived by calculation. Thus, measurement of these two phosphorous species did not meet the data completeness of 90%.

Four samples were collected at each fixed-station site during each index period. An additional eight samples were collected during the spatial mapping survey. Data variability as measured by the relative standard deviation averaged 39% and ranged from 7 to 134%, depending on the parameter (Table 18 and Table 19). Variability was most commonly in range of 30 to 60%, though the largest variability was observed for Phaeophytin, and nitrate and when values were close to or at the method detection limit such as for nitrite during the second index period. Total suspended particles, chlorophyll-*a,* and nutrient data were very similar to the other lagoon water quality parameters in that they were generally more similar between the upper and lower lagoon monitoring sites during a single index period and quite different between March and October.

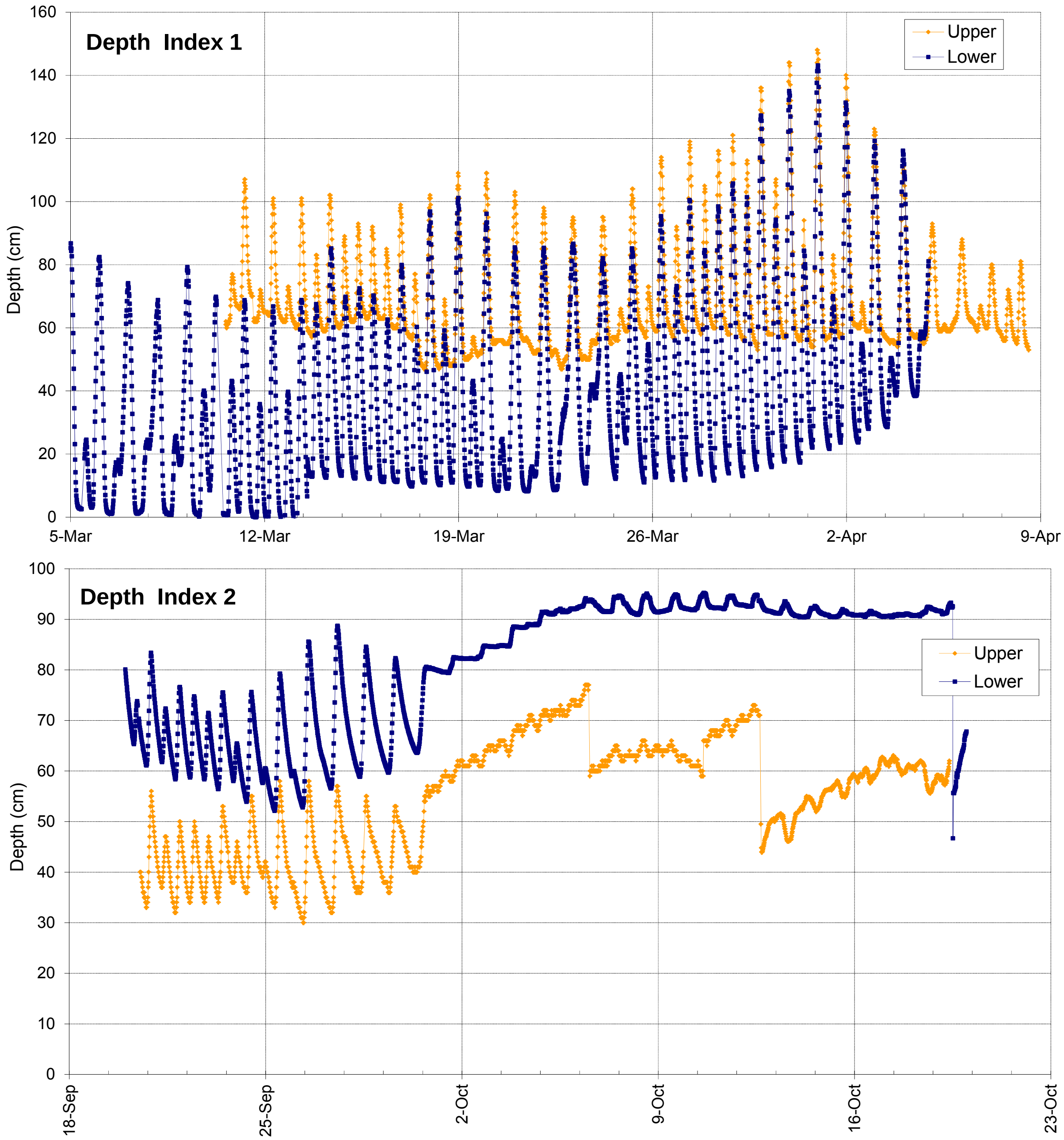


Figure 19. Comparison of lower and upper lagoon depth data during Index Period 1 (top plot) and Index Period 2 (bottom plot). Shifts in the upper lagoon data are a result of moving the sensor within the water column.

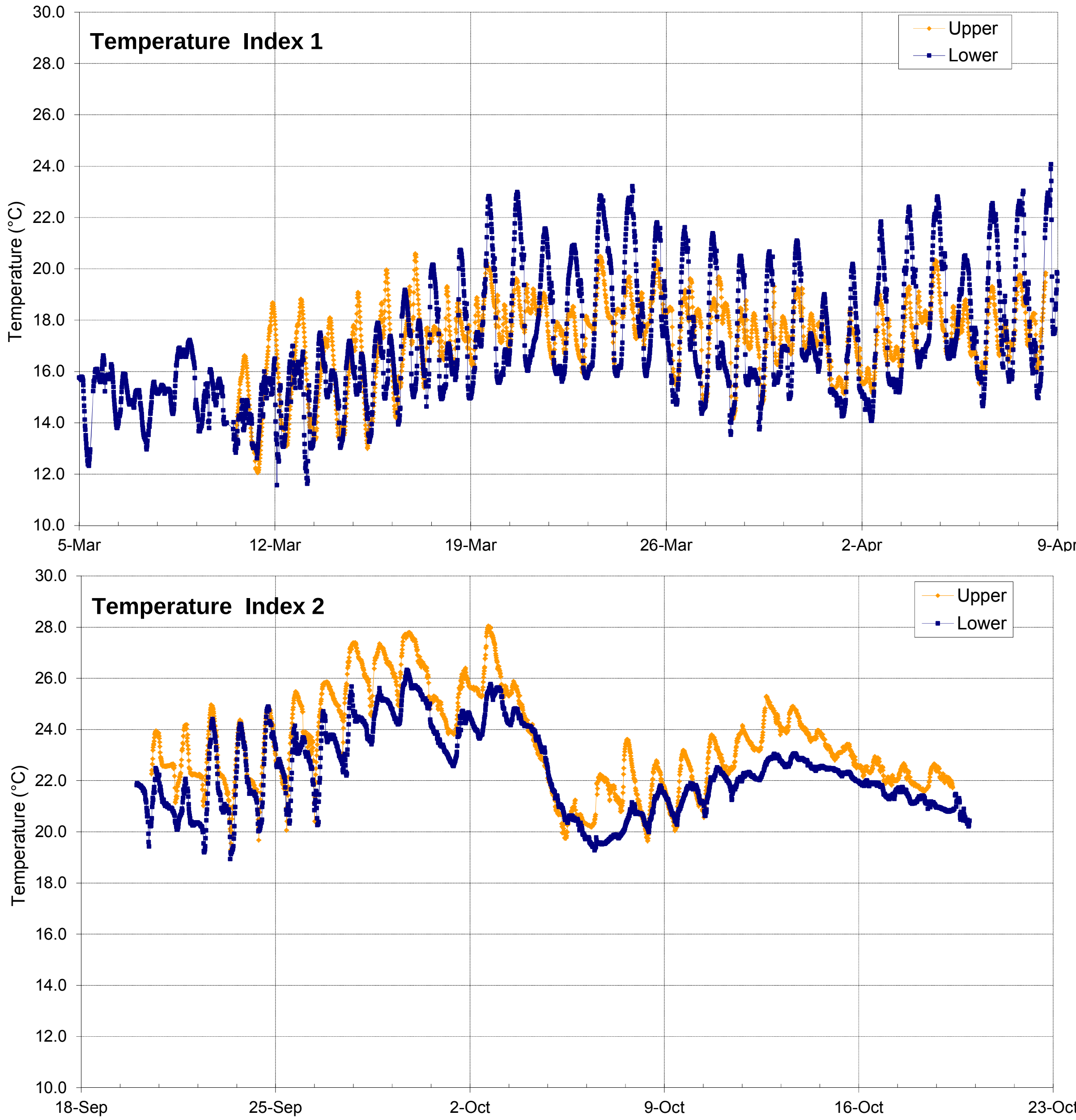
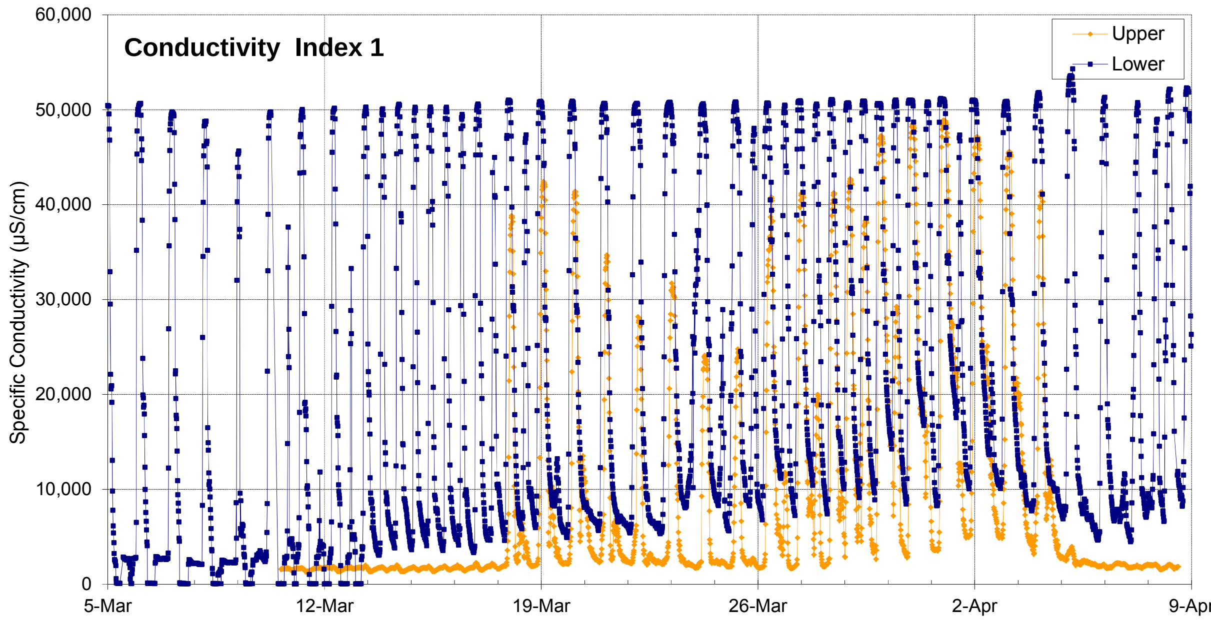


Figure 20. Comparison of lower and upper lagoon temperature data during Index Period 1 (top plot) and Index Period 2 (bottom plot).



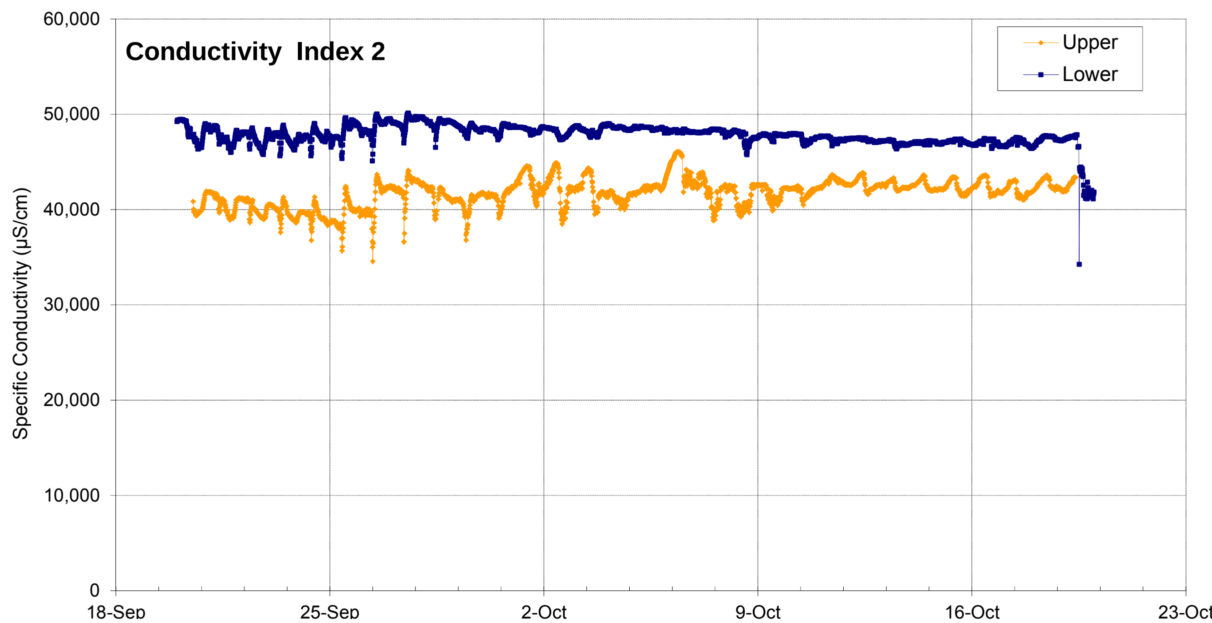
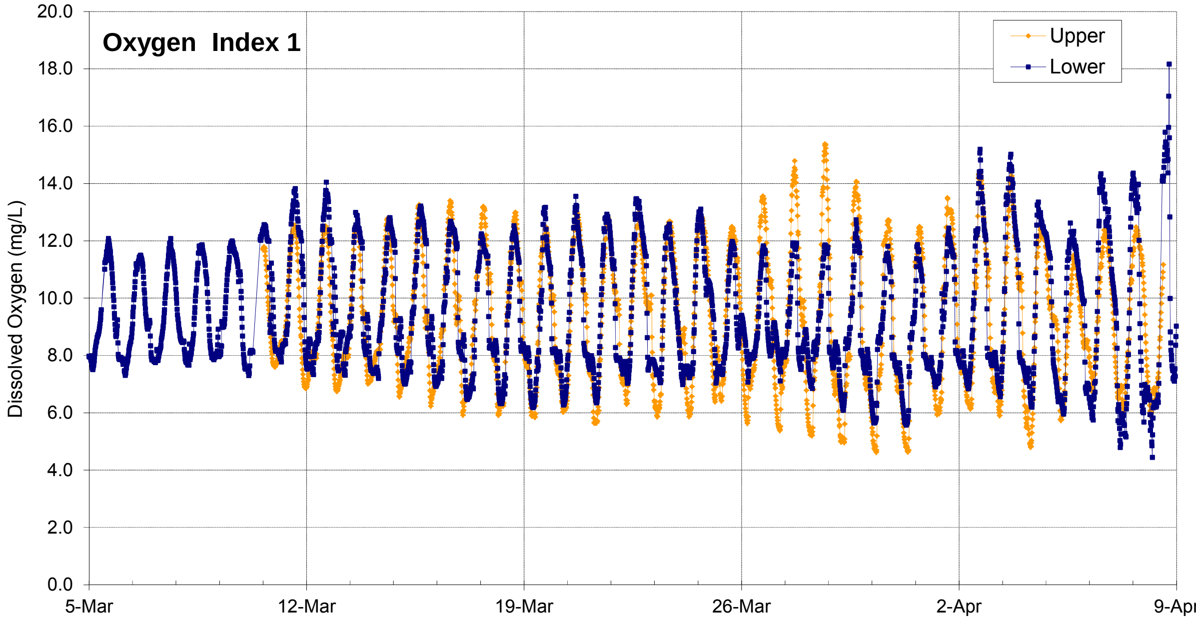


Figure 21. Comparison of lower and upper lagoon specific conductivity data during Index Period 1 (top plot) and Index Period 2 (bottom plot).



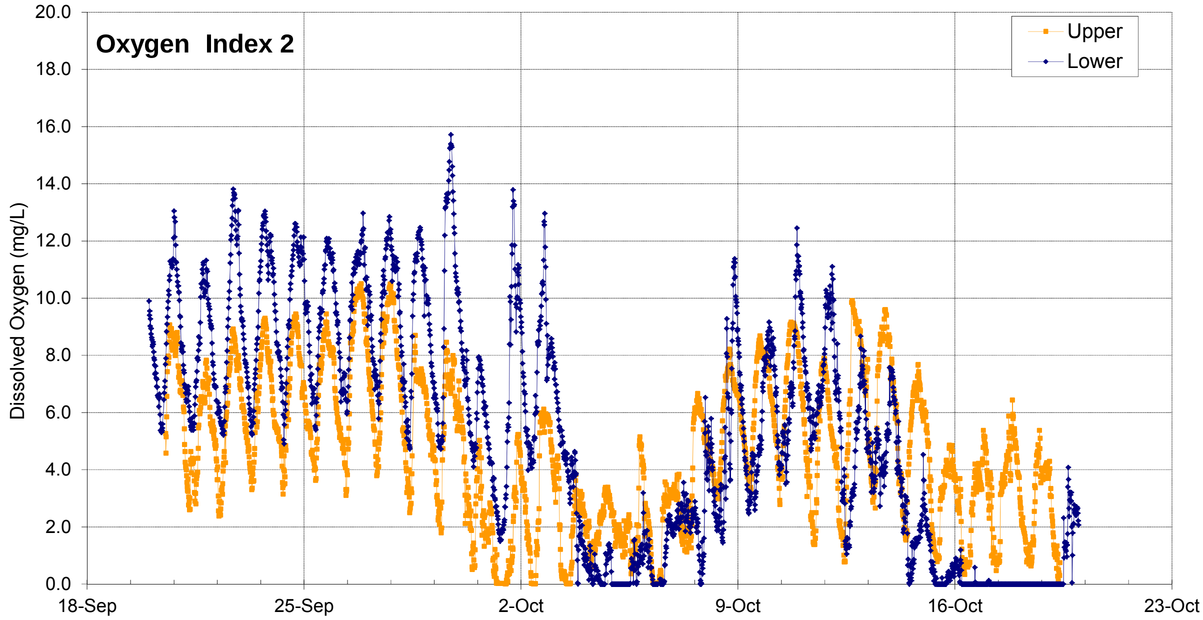


Figure 22. Comparison of lower and upper lagoon dissolved oxygen data during Index Period 1 (top plot) and Index Period 2 (bottom plot).

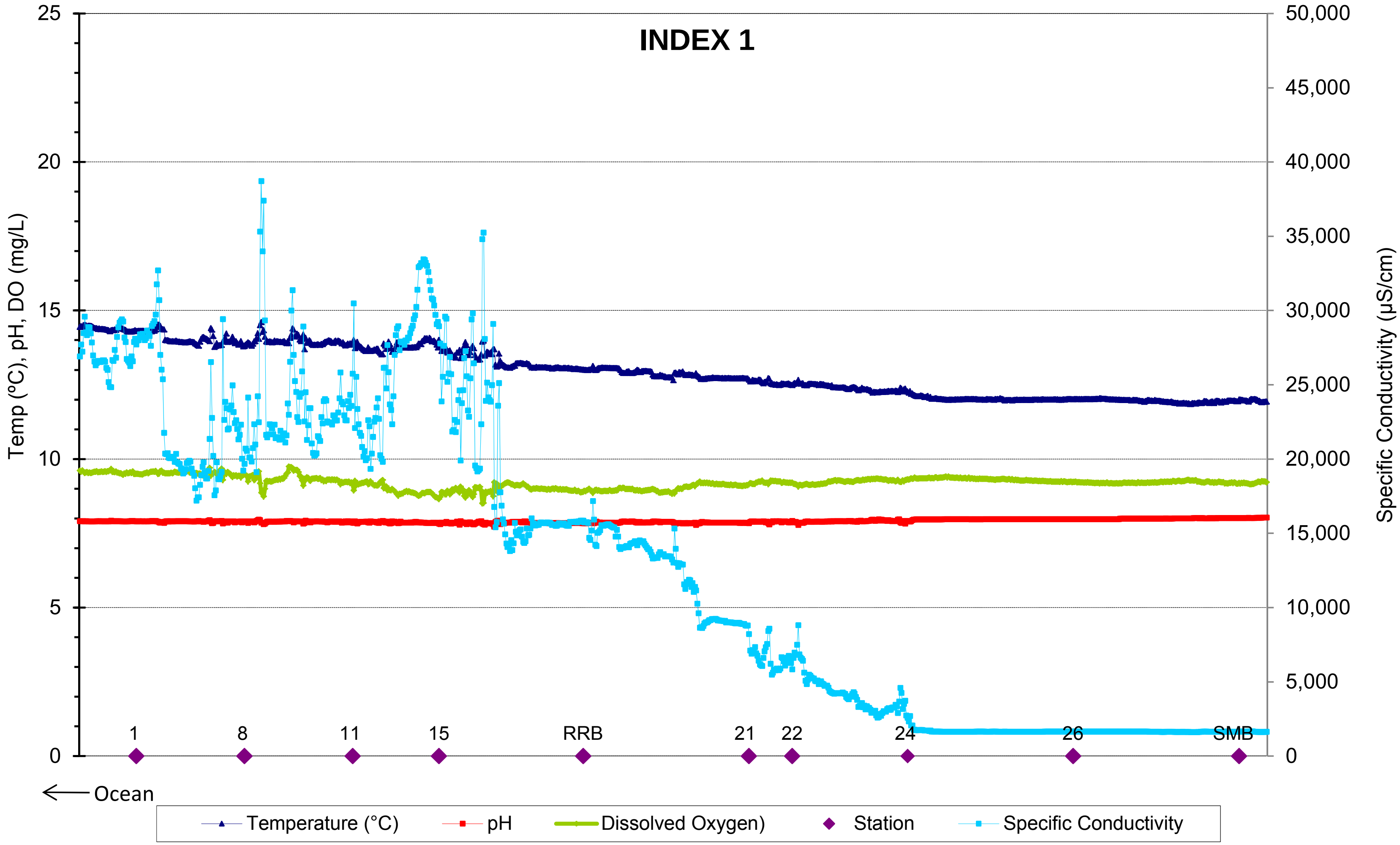


Figure 23. Index Period 1 spatial mapping survey results along the longitudinal transect from the lagoon mouth to the Stuart Mesa Bridge (SMB) on 10 March 2010. Station numbers represent where discrete water samples were collected.

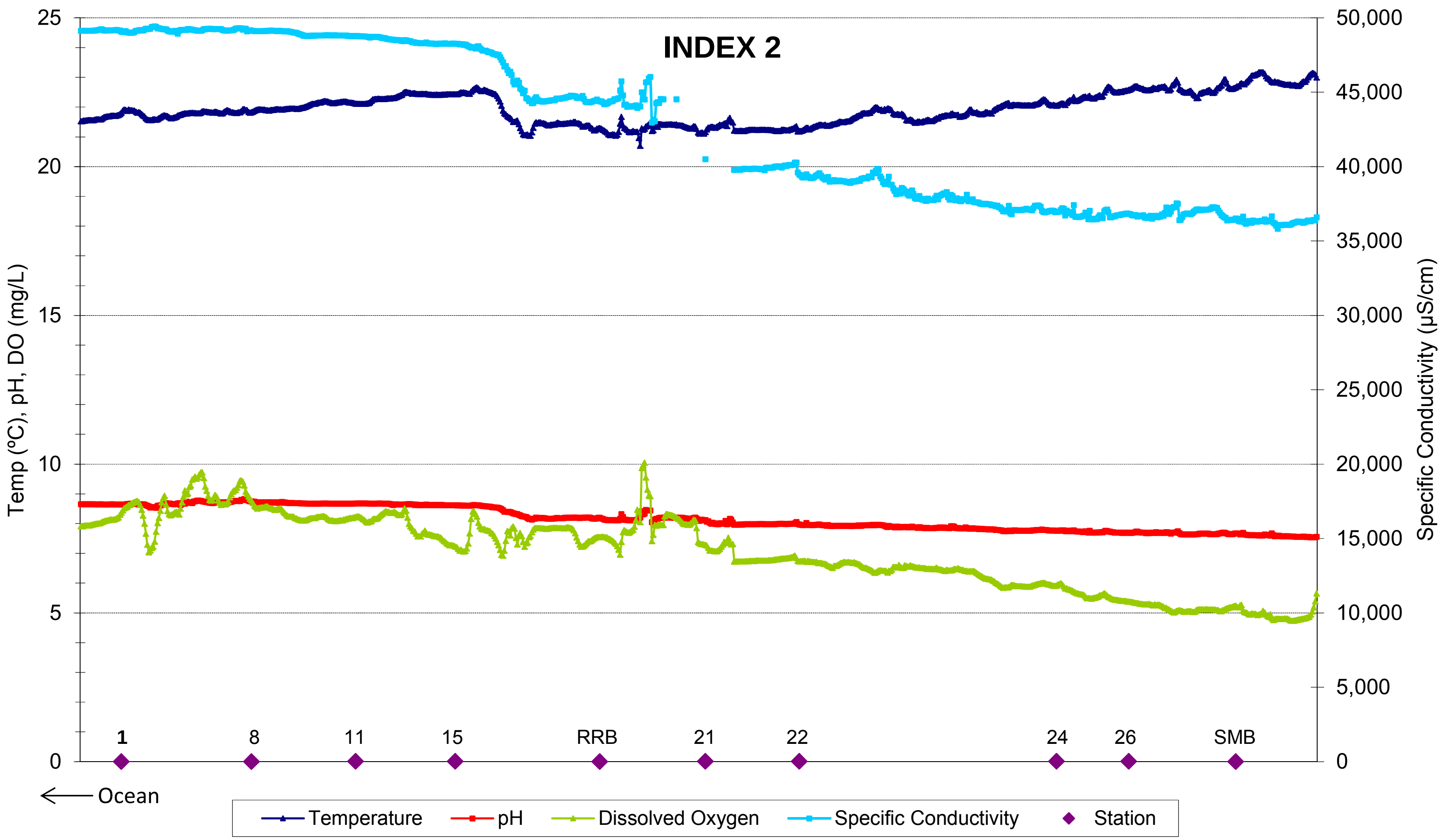


Figure 24. Index Period 2 spatial mapping survey results along the longitudinal transect from the lagoon mouth to the Stuart Mesa Bridge (SMB) on 12 October 2010. Station numbers represent where discrete water samples were collected. The survey was paused about the midpoint for more than 1.5 hours while the crew interacted with MCBCP staff. Specific conductivity data about the midpoint of the transect were removed as suspect.

Differences between the lower and upper lagoon during each index period are shown in Table 18 and Table 19. Statistically significant differences (P = 0.05) were only observed for dissolved organic nitrogen and for total-, total dissolved-, and phosphate-phosphorous. Higher average concentrations were observed in the upper lagoon each of these nutrients for both index periods. All parameters were statistically different from Index 1 to Index 2 (P = 0.05). Total suspended solids, total phosphorous, and chloropyll-*a* were higher in October by factors of ~2.5 to 3 while total nitrogen was lower by about a factor of 2. These changes were also observed for the individual species of phosphorous and nitrogen with the exception of particulate and organic nitrogen. It's not clear to what extent the mouth closure affected these spatial differences.

3.4.1 TSS

Total suspended solids ranged from 5 to 18 mg/L in March, increasing to between 17 and 48 mg/L in October. Overall, average concentrations in October were roughly 3.5 times higher than in March. Concentrations generally increased toward the mouth in March with a maximum at Station 8 just upstream from the lagoon mouth. The October distribution showed a maximum in the vicinity of the Railroad Bridge with values falling off evenly both upstream and downstream from there. The maximum was likely related to the earthern berm constructed there to support the new Railroad Bridge construction.

3.4.2 Nitrogen

Total nitrogen ranged between 0.63 to 2.0 mg/L in March and from 0.57 to 0.89 mg/L in October. Overall, concentrations were about a factor of two lower in October than in March. Dissolved nitrogen made up 95% of the nitrogen in March, 70% of which, was in the inorganic form, almost all as nitrate. This is in contrast to the ~50% of nitrogen found as dissolved in October, with only ~5% of that found in inorganic form. The decrease overall and in inorganic nitrogen was likely the result of a combination in decreased source(s) and consumption by the larger population of benthic algae present in the lagoon throughout the summer and fall. This result is consistent with the evaluation of the assimilative capacity of the Santa Margarita River upstream of the lagoon (Scott Thomas, Stetson Engineers, personal communication, 2011). Particulate nitrogen was the only fraction that increased from March to October. This correlated with the increase in TSS, but only represented a very small fraction of the total nitrogen. Total nitrogen concentrations increased by about a factor of two from the mouth to the upper lagoon in March but were relatively constant in October, except for nitrate and nitrite that were particularly elevated at the mouth.

3.4.3 Phosphorous

Total phosphorous ranged from 0.09 to 0.15 mg/L in March and from 0.16 to 0.41 mg/L in October. Overall, concentrations were about a factor of two higher in October than in March, which was the opposite of what was observed for nitrogen. The dissolved fraction (~80%) and phosphate (~60%) remained relatively constant fractions of the total during both time periods. Concentrations of total phosphorous generally increased upstream during both periods, about 30% in March and by more than a factor of two in October. The distributions and concentrations suggest, unlike nitrogen, a source of phosphorous persisted in the upper lagoon into the fall. The total nitrogen to phosphorous ratio in March averaged approximately 10 in March and 2 in October. The persistence of phosphorous is consistent with findings with the assimilative capacity of the upstream river source (Scott Thomas, Stetson Engineers, personal communication, 2011).

3.3.4 Chlorophyll

Chlorophyll-*a* concentrations in the water column ranged from 2.2 to 11.3 µg/L in March and from 4.8 to 34 µg/L in October. Overall, concentrations were roughly a factor of three higher in October. The active component of the chlorophyll was consistently about 80% of the total during both periods of time. Except for the exceptionally high value of ~11 µg/L measured at station 26 in the upper lagoon, the chlorophyll distribution generally decreased slightly upstream. The spatial distribution in October showed a maximum at the Railroad Bridge station. The higher chlorophyll in October reflected increased algal biomass in the water column along with visually observed elevated levels was consistent with the larger visual presence of benthic algae.

Total nitrogen, total phosphorous, total suspended solids, and chlorophyll-*a* values measured in this project were compared to data collected by SSC Pacific in 2006 through 2007 (SSC San Diego [SSC Pacific], 2007) for MCBCP and by CDM in 2008 for the Lagoon Investigative Order (CDM, 2009). These nutrient data are summarized in Table 19 and in Figure 25 and Figure 26 to assess inter-annual variability. Slight differences in the data included that the CDM data were collected in both late September and early October and that the SSC Pacific 2006–2007 TP data were calculated from the measured ortho-Phosphate value adjusted for the average value of o-P/TP (66%) observed for the CDM and SSC Pacific 2010 data. The lower lagoon average included data from all fixed and spatial mapping stations below the Railroad Bridge while the upper lagoon average included data from all stations above the Railroad Bridge. Both the CDM and SSC Pacific 2007 datasets may have had some influence from the intermittently discharging North County Transit District (NCTD) dewatering system outfall pipe near to the Railroad Bridge.

Average TN in the historical datasets generally showed a large decrease from March to October as was observed in the current dataset. The differences with season were also generally larger than the differences between lower and upper lagoon for the same season. Average Total Nitrogen was usually (0.80 - 5.2 mg/L) above the 1.0 mg/L Basin Plan objective in the lower lagoon in March and below the limit in October (0.43-1.8). The seasonal changes reflect both a reduction in source from wet weather to dry weather as well as preferential biological uptake during the dry season. While elevation above the limit was related to wet weather inputs, the values in 2006 through –2008 potentially reflect the additional intermittent NCTD discharge. There did not appear to be a specific inter-annual trend in the TN data. The March data appeared to be variable primarily dependent on changes in sources while the October data were relatively consistent.

In contrast, average TP in the historical datasets generally showed an increase from March to October. Seasonal differences were greater than spatial differences similar to what was observed for almost all water quality parameters. Total Phosphorous was usually above its 0.1-mg/L Basin Plan objective. Only the SSC San Diego [now SSC Pacific] 2007 dataset was below the limit (and is not related to the calculation method). The 2008 and 2010 datasets were consistent with a persistent river source of TP. It’s not known why the 2007 dataset was so much lower. Like the TN data, there did not appear to be a specific inter-annual trend in the TP data. In this case the March data appeared to be relatively consistent year to year while the October data were more variable and probably dependent on changes in the river source.

The plots shown in Figure 26 show an average TSS concentration that varied considerably from year to year. However, the elevated TSS values observed in the lower lagoon in 2008 are a result of two exceptionally high values measured in March and one in October. Without those three data points, the 2008 averages for both the lower and upper lagoon in March would have been 14 mg/L. It is not known if these data were compromised or not. The elevated levels measured in the lagoon in 2010 likely reflect erosion of the earthern berm at the Railroad Bridge as observed during the spatial

mapping survey. No clear inter-annual trends could be observed in the datasets. The averages without a few samples in 2008 and the influence of the Railroad Bridge berm, were relatively consistent.

The average historical chlorophylly-*a* data showed larger seasonal changes than spatial as observed for most water quality parameters (Figure 26). Variability of this parameter (1 µg/L to 29 µg/L) was greater from year-to-year than it was seasonally or spatially. The variability is a result of a dynamic estuarine system and a biological process that is driven by several factors.

The current water quality objective for nitrogen and phosphorous levels in California surface waters *states:*

> *"A desired goal in order to prevent plant nuisances in streams and other flowing waters appears to be 0.1 mg/l total P. These values are not to be exceeded more than 10% of the time unless studies of the specific body in question clearly show that water quality objective changes are permissible and changes are approved by the Regional Board. Analogous threshold values have not been set for nitrogen compounds; however, natural ratios of nitrogen to phosphorus are to be determined by surveillance and monitoring and upheld. If data are lacking, a ratio of N: P=10:1 shall be used.*"

Though there are current efforts by the SDRWQCB, the EPA, and Santa Margarita stakeholders to re-evaluate whether this objective is scientifically appropriate, the values measured in this study were evaluated against them. Total nitrogen levels measured in March exceeded the 1.0 mg/L objective 69% of the time while levels measured in October were all less than the objective. Total phosphorous exceeded the 0.1 mg/L objective in 88% of samples collected in March and in 100% of samples collected in October. For comparison purposes, the CDM 2008 dataset showed exceedances of nitrogen in 28% of the data in March and 38% in September and phosphorous exceedances 97% of the time in March and 79% for the same two periods, respectively. The differences reflect natural variability in sources, processes, and potentially from the methodology and analytical process. These variations need to be addressed when developing lagoon-specific water quality objectives.

3.5 INDEX PERIOD BENTHIC ALGAE DATA

Percent cover and macroalgal biomass were assessed along three transects during the two index periods. All three transects were sampled in March but because of high water levels when the lagoon mouth closed up in October, only two of the transects (T1 and T2) were sampled, and in these, only floating macroalgal biomass could be evaluated with samples collected at the ends of each transect. As such, the quantitative measures of the dataset were limited. Transect T2 was shifted downstream from its original sampling coordinates because of the water level.

Results of the benthic macroalgal surveys are shown in Table 22. There was very little cover or macroalgal biomass observed in March. Transects T1 and T3 were completely absent of macroalgae cover. There was up to 6% cover in quadrats within Transect 2. The only species observed was a string-like sea lettuce (Ulva spp.). The only sample collected for (others fell outside the delineator) had a dry weight of 0.1 g. There was no floating macroalgae at any of the three transect locations.

Results of the surveys in October showed a large increase in percent cover of macroalgae from that measured in March. Percent cover of floating algae ranged from 41 to 100% in the two transects. Two species, Ulva spp. and filamentous algae were found at both ends of Transect 1while only Ulva spp. was found only at the ends of Transect 2. Mat thickness was about 30 cm at both locations. The algal conditions were fresh at both locations. Example pictures of the large variation in marcoalgal

cover between the two index periods are shown in Figure 27. The October floating algal biomass values ranged between1.2 and 3.2 g and averaged 1.9 g dry weight.

Conversion of the dry weight values to biomass is based on the area of the delineator (D = 10 cm) used to capture the sample and the percent cover of the quadrat in which the sample was collected. The calculated dry-weight biomass was 0.025 g/m^2 in March was comparable to the zero value measured by SCCWRP in 2008 (SCCWRP, 2010). Biomass values ranged between 6.3 and 28.9 g/ m^2 and averaged 17.6 g/ m^2 in October. These values were considerably lower than the 238 g/m^2 (lower lagoon) and 44 g/m^2 (upper lagoon) dry weights measured by SCCWRP in 2008.

Table 12. Discrete sample analytical results for TSS and nitrogen compounds collected weekly at two fixed stations and during spatial mapping during Index Period 1 (March/April). Values for the two fixed-station sites are repeated in the spatial mapping portion of the table. RRB suffix refers to Railroad Bridge monitoring site. SMB suffix refers to the Stuart Mesa Bridge monitoring site. Suffixes –S1 through –S26 refer to spatial mapping locations. The Basin Plan water quality objective for TN is 1.0 mg/L.

INDEX 1

Segment 1 Railroad Bridge

SAMPLE ID	DATE	TSS (mg/l)	NH_4-N (mg N/L)	NO_2-N (mg N/L)	NO_3-N (mg N/L)	TPN (mg N/L)	TDN (mg N/L)	DON (mg N/L)	TN (mg N/L)
SM-I1-D1-S1-RRB	03/05/2010	8.70	0.135	0.0084	1.352	0.0604	1.89	0.40	1.95
SM-I1-D2-S1-RRB	03/10/2010	8.10	0.071	0.0081	1.142	0.0564	1.40	1.33	1.46
SM-I1-D3-S1-RRB	03/17/2010	5.50	0.024	0.0076	0.330	0.1450	0.58	0.56	0.73
SM-I1-D4-S1-RRB	03/24/2010	13.30	0.040	0.0041	0.233	0.0752	0.58	0.54	0.66

Segment 2 Stuart Mesa Bridge

SAMPLE ID	DATE	TSS (mg/l)	NH_4-N (mg N/L)	NO_2-N (mg N/L)	NO_3-N (mg N/L)	TPN (mg N/L)	TDN (mg N/L)	DON (mg N/L)	TN (mg N/L)
SM-I1-D1-S2-SMB	03/05/2010	5.50	0.033	0.0057	1.344	0.0443	1.69	1.66	1.73
SM-I1-D2-S2-SMB	03/10/2010	5.50	0.022	0.0057	1.444	0.0672	1.83	1.81	1.90
SM-I1-D3-S2-SMB	03/17/2010	18.20	0.029	0.0051	0.903	0.0504	1.20	1.17	1.25
SM-I1-D4-S2-SMB	03/24/2010	5.30	0.026	0.0035	0.251	0.0484	0.58	0.55	0.63

Spatial Mapping

SAMPLE ID	DATE	TSS (mg/l)	NH_4-N (mg N/L)	NO_2-N (mg N/L)	NO_3-N (mg N/L)	TPN (mg N/L)	TDN (mg N/L)	DON (mg N/L)	TN (mg N/L)
SM-I1-D2-S1	03/10/2010	11.40	0.032	0.0069	0.878	0.0699	1.06	1.03	1.13
SM-I1-D2-S8	03/10/2010	15.40	0.033	0.0055	0.731	0.1730	0.92	0.89	1.09
SM-I1-D2-S1-RRB	03/10/2010	8.10	0.071	0.0081	1.142	0.0564	1.40	1.33	1.46
SM-I1-D2-S11	03/10/2010	11.40	0.029	0.0070	0.917	0.0779	1.08	1.05	1.16
SM-I1-D2-S15	03/10/2010	9.90	0.031	0.0074	0.957	0.1090	1.16	1.13	1.27
SM-I1-D2-S21	03/10/2010	7.40	0.028	0.0075	1.273	0.0766	1.52	1.49	1.60
SM-I1-D2-S22	03/10/2010	5.40	0.030	0.0068	1.333	0.0739	1.65	1.62	1.72
SM-I1-D2-S24	03/10/2010	7.10	0.028	0.0065	1.374	0.0739	1.75	1.72	1.82
SM-I1-D2-S26	03/10/2010	6.70	0.027	0.0056	1.464	0.0853	1.90	1.87	1.99
SM-I1-D1-S2-SMB	03/10/2010	5.50	0.022	0.0057	1.444	0.0672	1.83	1.81	1.90

Table 13. Discrete sample analytical results for phosphorous and chlorophyll compounds collected weekly at two fixed stations and during spatial mapping during Index Period 1 (March/April). Values for the two fixed-station sites are repeated in the spatial mapping portion of the table. RRB suffix refers to Railroad Bridge monitoring site. SMB suffix refers to the Stuart Mesa Bridge monitoring site. Suffixes –S1 through –S26 refer to spatial mapping locations. The Basin Plan water quality objective for TP is 0.1 mg/L.

INDEX 1

Segment 1 Railroad Bridge

SAMPLE ID	DATE	PO_4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	Active Chl (ug/L)
SM-I1-D1-S1-RRB	03/05/2010	0.0882	0.1177	0.1359	0.0182	2.83	0.93	2.37
SM-I1-D2-S1-RRB	03/10/2010	0.0789	0.0910	0.1074	0.0164	2.21	0.77	1.82
SM-I1-D3-S1-RRB	03/17/2010	0.0380	0.0606	0.1387	0.0781	2.19	0.56	1.91
SM-I1-D4-S1-RRB	03/24/2010	0.0910	0.1125	0.1400	0.0275	3.66	1.72	2.80

Segment 2 Stuart Mesa Bridge

SAMPLE ID	DATE	PO_4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	Active Chl (ug/L)
SM-I1-D1-S2-SMB	03/05/2010	0.0880	0.1115	0.1402	0.0287	2.24	0.64	1.92
SM-I1-D2-S2-SMB	03/10/2010	0.0832	0.1105	0.1323	0.0218	2.32	0.66	1.99
SM-I1-D3-S2-SMB	03/17/2010	0.0963	0.1151	0.1402	0.0251	4.04	0.57	3.76
SM-I1-D4-S2-SMB	03/24/2010	0.1050	0.1270	0.1476	0.0206	3.05	0.77	2.66

Spatial Mapping

SAMPLE ID	DATE	PO_4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	Active Chl (ug/L)
SM-I1-D2-S1	03/10/2010	0.0642	0.0765	0.1139	0.0374	2.96	1.12	2.40
SM-I1-D2-S8	03/10/2010	0.0518	0.0759	0.0906	0.0147	3.19	1.24	2.57
SM-I1-D2-S1-RRB	03/10/2010	0.0789	0.0910	0.1074	0.0164	2.21	0.77	1.82
SM-I1-D2-S11	03/10/2010	0.0655	0.0880	0.0927	0.0047	3.81	1.42	3.10
SM-I1-D2-S15	03/10/2010	0.0658	0.0796	0.1055	0.0259	3.36	1.20	2.76
SM-I1-D2-S21	03/10/2010	0.0874	0.1009	0.1161	0.0152	2.66	0.82	2.25
SM-I1-D2-S22	03/10/2010	0.0820	0.1080	0.1318	0.0238	2.58	0.74	2.21
SM-I1-D2-S24	03/10/2010	0.0897	0.1020	0.1290	0.0270	2.42	0.64	2.10
SM-I1-D2-S26	03/10/2010	0.0900	0.1058	0.1304	0.0246	11.31	3.83	9.40
SM-I1-D1-S2-SMB	03/10/2010	0.0832	0.1105	0.1323	0.0218	2.32	0.66	1.99

Table 14. Discrete sample analytical results for TSS and nitrogen compounds collected weekly at two fixed stations and during spatial mapping during Index Period 2 (Sep/Oct). Values for the two fixed-station sites are repeated in the spatial mapping portion of the table. Note lower lagoon monitoring was conducted at the Riprap site, not Railroad Bridge site. SMB suffix refers to the Stuart Mesa Bridge monitoring site. Suffixes –S1 through –S26 refer to spatial mapping locations. Grayed out cell values were below the detection limit. The Basin Plan water quality objective for TN is 1.0 mg/L.

INDEX 2

Segment 1 Railroad Bridge

SAMPLE ID	DATE	TSS	NH4-N	NO2-N	NO3-N	TPN	TDN	DON	TN
		(mg/l)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)
SM-12-D1-RRB	09/28/2010	31.10	0.013	0.0006	0.0019	0.569	0.321	0.875	0.89
SM-12-D2-RRB	10/06/2010	32.90	0.011	0.0013	0.0292	0.257	0.403	0.619	0.66
SM-12-D3-RRB	10/12/2010	30.30	0.023	0.0024	0.0312	0.322	0.418	0.683	0.74
SM-12-D4-RRB	10/19/2010	32.90	0.036	0.0055	0.0377	0.347	0.423	0.691	0.77

Segment 2 Stuart Mesa Bridge

SAMPLE ID	DATE	TSS	NH4-N	NO2-N	NO3-N	TPN	TDN	DON	TN
		(mg/l)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)
SM-12-D1-SMB	09/28/2010	19.20	0.010	0.0006	0.0024	0.257	0.363	0.607	0.62
SM-12-D2-SMB	10/06/2010	42.90	0.016	0.0006	0.0044	0.396	0.344	0.719	0.74
SM-12-D3-SMB	10/12/2010	17.30	0.019	0.0006	0.0045	0.104	0.546	0.626	0.65
SM-12-D4-SMB	10/19/2010	48.30	0.016	0.0015	0.0083	0.379	0.391	0.744	0.77

Spatial Mapping

SAMPLE ID	DATE	TSS (mg/l)	NH4-N (mg N/L)	NO2-N (mg N/L)	NO3-N (mg N/L)	TPN (mg N/L)	TDN (mg N/L)	DON (mg N/L)	TN (mg N/L)
SM-12-D3-S1	10/12/2010	21.80	0.024	0.0068	0.1782	0.268	0.512	0.571	0.78
SM-12-D3-S8	10/12/2010	18.70	0.017	0.0006	0.0102	0.207	0.363	0.542	0.57
SM-12-D3-S11	10/12/2010	22.60	0.018	0.0006	0.0089	0.214	0.356	0.543	0.57
SM-12-D3-S15	10/12/2010	21.30	0.021	0.0033	0.0472	0.200	0.44	0.569	0.64
SM-12-D3-S19-RRB	10/12/2010	30.30	0.023	0.0024	0.0312	0.322	0.418	0.683	0.74
SM-12-D3-S21	10/12/2010	20.70	0.014	0.0010	0.0109	0.303	0.437	0.714	0.74
SM-12-D3-S22	10/12/2010	22.20	0.013	0.0006	0.0062	0.229	0.441	0.650	0.67
SM-12-D3-S24	10/12/2010	18.50	0.037	0.0006	0.0033	0.223	0.437	0.619	0.66
SM-12-D3-S26	10/12/2010	17.60	0.021	0.0009	0.0022	0.198	0.422	0.596	0.62
SM-12-D3-SMB	10/12/2010	17.30	0.019	0.0006	0.0045	0.104	0.546	0.626	0.65

Table 15. Discrete sample analytical results for phosphorous and chlorophyll compounds collected weekly at two fixed-stations and during spatial mapping during Index Period 2 (Sep/Oct). Values for the two fixed-station sites are repeated in the spatial mapping portion of the table. Note that dissolved and particulate phosphorous were not analyzed in this dataset (na). Note also lower lagoon monitoring was conducted at the Riprap site, not Railroad Bridge site. SMB suffix refers to the Stuart Mesa Bridge monitoring site. Suffixes –S1 through –S26 refer to spatial mapping locations. The Basin Plan water quality objective for TP is 0.1 mg/L.

INDEX 2

Segment 1 Railroad Bridge

SAMPLE ID	DATE	PO4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	ACTIVE Chl (ug/L)
SM-12-D1-RRB	09/28/2010	0.1301	na	0.2886	na	33.98	20.37	23.93
SM-12-D2-RRB	10/06/2010	0.2849	na	0.3877	na	10.50	4.21	8.42
SM-12-D3-RRB	10/12/2010	0.1585	na	0.3102	na	13.3	2.44	12.09
SM-12-D4-RRB	10/19/2010	0.2129	na	0.3395	na	13.17	4.07	11.15

Segment 2 Stuart Mesa Bridge **Segment 2 Stuart Mesa Bridge**

SAMPLE ID	DATE	PO4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	ACTIVE Chl (ug/L)
SM-12-D1-SMB	09/28/2010	0.1853	na	0.3066	na	7.19	3.57	5.43
SM-12-D2-SMB	10/06/2010	0.3208	na	0.4145	na	16.87	6.65	13.59
SM-12-D3-SMB	10/12/2010	0.1983	na	0.3580	na	6.44	3.27	4.83
SM-12-D4-SMB	10/19/2010	0.2494	na	0.3963	na	8.97	3.79	7.10

Spatial Mapping **Spatial Mapping**

SAMPLE ID	DATE	PO4-P (mg P/L)	TDP (mg P/L)	TP (mg P/L)	TPP (mg P/L)	Total Chl-a (ug/L)	PHAEO-Chl (ug/L)	ACTIVE Chl (ug/L)
SM-12-D3-S1	10/12/2010	0.0702	na	0.1568	na	9.52	2.25	8.41
SM-12-D3-S8	10/12/2010	0.1077	na	0.1984	na	5.84	1.84	4.93
SM-12-D3-S11	10/12/2010	0.1239	na	0.2034	na	8.70	1.71	7.85
SM-12-D3-S15	10/12/2010	0.1221	na	0.2202	na	10.14	1.31	9.50
SM-12-D3-S1-RRB	10/12/2010	0.1585	na	0.3102	na	13.3	2.44	12.09
SM-12-D3-S21	10/12/2010	0.1791	na	0.2921	na	10.61	2.45	9.39
SM-12-D3-S22	10/12/2010	0.2162	na	0.3340	na	6.45	2.44	5.24
SM-12-D3-S24	10/12/2010	0.2096	na	0.3562	na	5.60	2.86	4.19
SM-12-D3-S26	10/12/2010	0.2107	na	0.3464	na	4.80	2.73	3.46
SM-12-D3-SMB	10/12/2010	0.1983	na	0.3580	na	6.44	3.27	4.83

Table 16. Discrete water sample laboratory duplicate (DUP) QA/QC analyses and relative percent difference (RPD) found for nutrient parameters.

Index 1

Nutrient	Lab ID	DUP1	DUP2	RPD
		mg/L	mg/L	%
TDP	3T	0.0921	0.0891	-3.4%
TDN	3T	1.00	0.99	-1.0%
NO_2+NO_3	6	1.490	1.450	-2.8%
NO_2+NO_3	7	0.338	0.338	0.0%
NO_2+NO_3	16	0.256	0.252	-1.6%
NO_2	14	0.0069	0.0070	1.4%
NH_4	14	0.032	0.031	-3.2%
PO_4	14	0.0642	0.0634	-1.3%
PN	6	0.0860	0.0846	-1.7%
PN	15	0.0544	0.0463	-17.5%

Index 2

Nutrient	Lab ID	DUP1	DUP2	RPD
		mg/L	mg/L	%
TP	81	0.2792	0.2979	6.3%
TP	91	0.2839	0.3003	5.5%
NO_2+NO_3	92	0.0067	0.0068	1.5%
NO_2	53	0.0014	0.0014	0.0%
NO_2	91	0.0010	0.0011	9.1%
NH_4	53	0.011	0.012	8.3%
NH_4	91	0.014	0.014	0.0%
PO_4	53	0.2870	0.2829	-1.4%
PO_4	91	0.1799	0.1783	-0.9%
PN	D5-S26	0.1940	0.2010	3.5%

Table 17. Discrete water sample spiked QA/QC analyses and relative percent difference (RPD) found for nutrient parameters.

Index 1

Nutrient	Lab ID	Measured	Spiked	RPD
		mg/L	mg/L	%
TDP	3D	0.1204	0.1231	2.2%
TDN	3D	1.56	1.65	5.5%
NO_2	7	0.0255	0.026	1.9%
NH_4	7	0.107	0.108	0.9%
PO_4	7	0.0701	0.0684	-2.5%

Index 2

Nutrient	Lab ID	Measured	Spiked	RPD
		mg/L	mg/L	%
TN	83	1.45	1.41	-2.8%
NO_2+NO_3	88	0.0578	0.0544	-6.3%

Table18. Lower and upper lagoon averages and relative standard deviations for the March Index Period 1 sampling period. Grayed out cells show significant statistical differences (two-tail t-test) between measurements (fixed and spatial samples) made in each segment of the lagoon.

March Index 1

	TSS	NH4-N	NO2-N	NO3-N	TPN	TDN	DON	TN
	(mg/l)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)
Lower Lagoon								
Average	10.46	0.05	0.01	0.82	0.10	1.08	0.21	1.18
RSD	30%	76%	21%	46%	45%	40%	44%	35%
Upper Lagoon								
Average	26.45	0.02	0.003	0.04	0.30	0.40	0.34	0.70
RSD	22%	38%	91%	132%	41%	15%	7%	16%
t-Test Upper vs. Lower	0.157	0.129	0.126	0.094	0.075	0.066	**0.025**	0.082

SAMPLE ID	PO4-P	TDP	TP	TPP	Total Chl-a	PHAEO-Chl	ACTIVE Chl
	(mg P/L)	(mg P/L)	(mg P/L)	(mg P/L)	(ug/L)	(ug/L)	(ug/L)
Lower Lagoon							
Average	0.07	0.09	0.12	0.03	3.03	1.12	2.47
RSD	26%	22%	17%	81%	20%	33%	18%
Upper Lagoon							
Average	0.09	0.11	0.13	0.02	3.83	1.08	3.29
RSD	8%	8%	7%	18%	81%	103%	77%
t-Test Upper vs. Lower	**0.006**	**0.009**	**0.040**	0.586	0.483	0.928	0.384

Table 19. Lower and upper lagoon averages and relative standard deviations for the October Index Period 2 sampling period. Grayed out cells show significant statistical differences (two-tail t-test) between measurements (fixed and spatial samples) made in each segment of the lagoon.

October Index 2

	TSS	NH4-N	NO2-N	NO3-N	TPN	TDN	DON	TN
	(mg/l)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)
Lower Lagoon								
Average	26.45	0.02	0.003	0.04	0.30	0.40	0.34	0.70
RSD	22%	38%	91%	132%	41%	15%	7%	16%
Upper Lagoon								
Average	25.84	0.02	0.001	0.01	0.26	0.42	0.40	0.68
RSD	48%	46%	41%	58%	37%	15%	15%	9%
t-Test Upper vs. Lower	0.901	0.606	0.050	0.081	0.513	0.558	**0.021**	0.681

SAMPLE ID	PO4-P	TDP	TP	TPP	Total Chl-a	PHAEO-Chl	ACTIVE Chl
	(mg P/L)	(mg P/L)	(mg P/L)	(mg P/L)	(ug/L)	(ug/L)	(ug/L)
Lower Lagoon							
Average	0.15		0.26		13.14	4.78	10.79
RSD	45%		31%		67%	134%	53%
Upper Lagoon							
Average	0.22		0.35		8.37	3.47	6.65
RSD	21%		12%		47%	40%	50%
t-Test Upper vs. Lower	**0.030**		**0.016**		0.180	0.581	0.101

Table 20. Lagoon-wide averages and relative standard deviations for the March Index Period 1 and October Index Period 2 sampling periods. Grayed out cells show significant statistical differences (two-tail t-test) between measurements (fixed and spatial samples) made during each index period.

Lagoon-Wide

	TSS (mg/l)	NH4-N (mg N/L)	NO2-N (mg N/L)	NO3-N (mg N/L)	TPN (mg N/L)	TDN (mg N/L)	DON (mg N/L)	TN (mg N/L)
March Index 1								
Average	9.05	0.04	0.01	1.00	0.08	1.30	0.26	1.38
RSD	43%	73%	22%	43%	43%	36%	35%	33%
October Index 2								
Average	26.14	0.02	0.002	0.02	0.28	0.41	0.37	0.69
RSD	36%	41%	111%	180%	39%	14%	15%	13%
t-Test March vs. October	**1.9E-07**	**1.3E-02**	**9.8E-09**	**3.9E-10**	**8.2E-08**	**2.8E-08**	**2.7E-04**	**2.1E-06**

	PO4-P	TDP	TP	TPP	Total Chl-a	PHAEO-Chl	ACTIVE Chl
March Index 1	(mg P/L)	(mg P/L)	(mg P/L)	(mg P/L)	(ug/L)	(ug/L)	(ug/L)
Average	0.08	0.10	0.12	0.03	3.43	1.10	2.88
RSD	22%	19%	14%	62%	64%	73%	63%
October Index 2							
Average	0.19		0.31		10.76	4.12	8.72
RSD	36%		25%		65%	110%	58%
t-Test March vs. October	**7.3E-07**		**2.5E-10**		**3.8E-04**	**1.3E-02**	**1.3E-04**

Table 21. Average total nitrogen, total phosphorous, total suspended solids, and chlorophyll-*a* for multiple datasets. The datasets include measurements from this study as well as those collected in 2008 for the Lagoon Investigative Order (CDM, 2009), and in 2006/2007 (SSC San Diego [now SSC Pacific], 2007) for MCBCP. Total phosphorous in the SSC San Diego [now SSC Pacific] 2007 dataset was calculated from measured ortho-Phosphate by adjusting the value by the average relative amount of o-P/TP (66%) measured in the CDM 2008 and SSC 2010 datasets. Note that removal of three values of TSS in the CDM March dataset would result in average values of 14 mg/L.

	TN			TP		
	SSC 2007	CDM 2008	SSC 2010	SSC 2007	CDM 2008	SSC 2010
March Lower	3.882	5.254	1.180	0.126	0.224	0.116
March Upper	4.470	0.795	1.580	0.227	0.133	0.133
October Lower	0.523	1.754	0.703	0.031	0.103	0.263
October Upper	0.429	0.683	0.684	1.061	0.428	0.351
n	54	56	32	54	56	32

	TSS			Chl-*a*		
	SSC 2007	CDM 2008	SSC 2010	SSC 2007	CDM 2008	SSC 2010
March Lower	4.00	119.838	10.160	5.42	28.941	3.03
March Upper	7.68	20.052	7.64	8.52	18.928	3.83
October Lower	8.35	6.773	26.45	1.21	3.706	13.14
October Upper	4.14	3.536	25.84	0.96	3.907	8.37
n	20	56	12	33	56	12

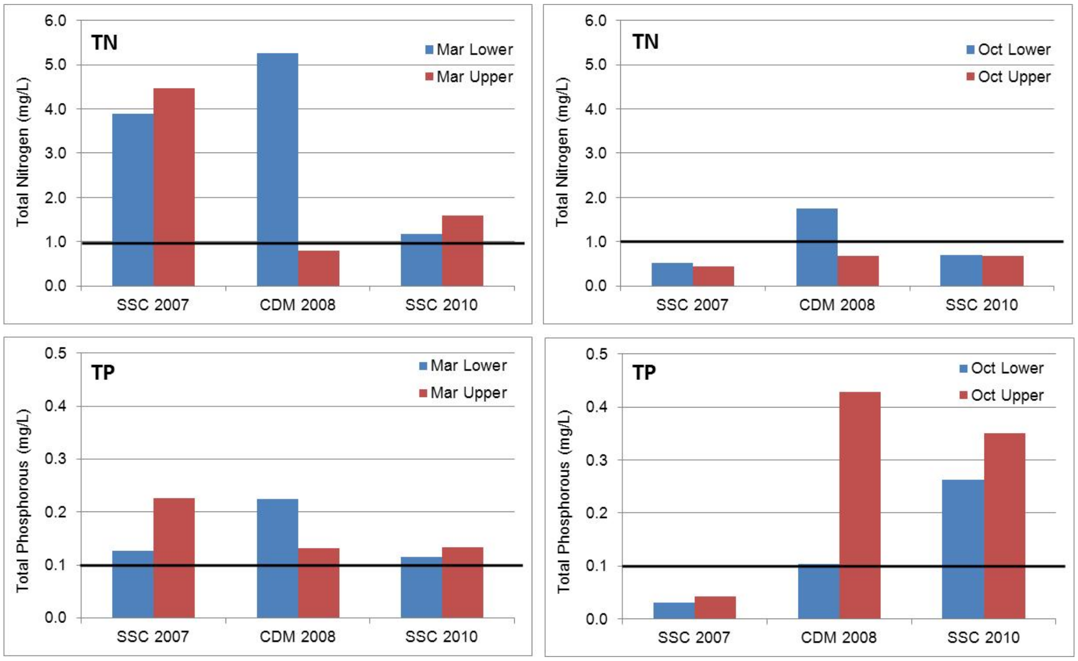


Figure 25. Average values of TN (top) and TP (bottom) measured in the lower and upper lagoon in March and October for various datasets as described in Table 19 above. The thick lines show the Basin Plan objectives for these nutrients.

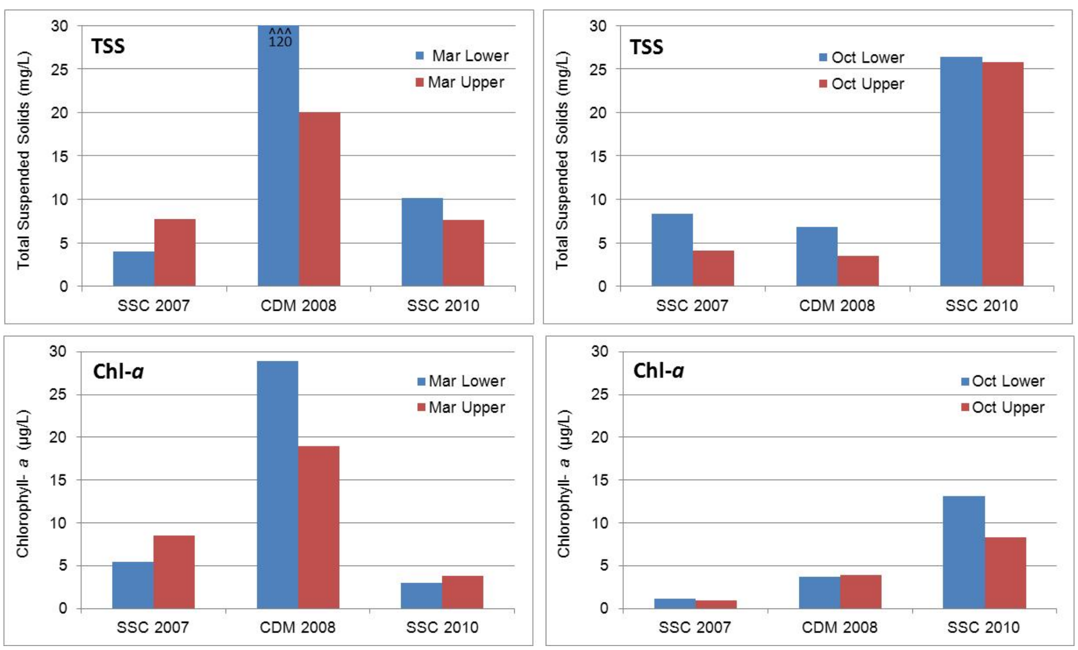


Figure 26. Average total suspended solids (top) and chlorophyll-*a* (bottom) measured in the lower and upper lagoon in March and October for various datasets as described in Table 19 above. Note that the average TSS for the lower lagoon measured by CDM in 2008 was 120 mg/L.

Table 22. Summary of benthic macroalgae survey results for Index 1 (top) and Index Period 2 (bottom). Distance is from start of transect. A (*) indicates randomly selected quadrat for biomass collection if present in delineator. A (*N) indicates biomass present but did not fall within delineator. Biomass was collected from both transect endpoints for T1 and T2 in October. The T3 site was inaccessible for sampling because of elevated water depth with the lagoon mouth closed.

Index 1

Transect	Transect Start/End	Longitude (Degrees West)	Latitude (Degrees North)	Quadrat	Distance (m)	Bare	Species	Quadrats with Species Present	Biomass Collected	Percent Cover	Wet Weight (g)	Dry Weight (g)
T1	Start	117.396339	33.237861	1	2	49	none	0	no	0%	-	-
	-	-	-	2	7	49	none	0	yes	0%	-	-
	-	-	-	3	12	49	none	0	yes	0%	-	-
	-	-	-	4	17	49	none	0	no	0%	-	-
	-	-	-	5	22	49	none	0	yes	0%	-	-
	-	-	-	6	27	49	none	0	no	0%	-	-
	-	-	-	7	32	49	none	0	yes	0%	-	-
	-	-	-	8	37	49	none	0	no	0%	-	-
	-	-	-	9	42	49	none	0	yes	0%	-	-
	End	117.396888	33.237801	10	50	49	none	0	no	0%	-	-
T2	Start	117.408174	33.235465	1	2	49	none	0	no	0%	-	-
	-	-	-	2	7	48	Ulva (string-like)	1	no	2%	-	-
	-	-	-	3	12	48	Ulva (string-like)	1	yes	2%	0.2	<.1
	-	-	-	4	17	49	none	0	no	0%	-	-
	-	-	-	5	22	49	none	0	no	2%	-	-
	-	-	-	6	27	49	none	0	no	0%	-	-
	-	-	-	7	32	47	Ulva (string-like)	2	no	4%	-	-
	-	-	-	8	37	46	Ulva (string-like)	3	no	6%	-	-
	-	-	-	9	42	49	none	0	yes	0%	-	-
	End	117.408695	33.235420	10	50	49	none	0	no	0%	-	-
T3	Start	117.412498	33.234173	1	2	49	none	0	no	0%	-	-
	-	-	-	2	7	49	none	0	yes	0%	-	-
	-	-	-	3	12	49	none	0	yes	0%	-	-
	-	-	-	4	17	49	none	0	no	0%	-	-
	-	-	-	5	22	49	none	0	yes	0%	-	-
	-	-	-	6	27	49	none	0	no	0%	-	-
	-	-	-	7	32	49	none	0	yes	0%	-	-
	-	-	-	8	37	49	none	0	no	0%	-	-
	-	-	-	9	42	49	none	0	yes	0%	-	-
	End	117.412986	33.234023	10	50	49	none	0	no	0%	-	-

Index 2

Transect	Position	Longitude (Degrees West)	Latitude (Degrees North)	Quadrat	Distance (m)	Bare	Species	Quadrats with Species Present	Biomass Collected	Percent Cover	Wet Weight (g)	Dry Weight (g)
T1	Start	117.396400	33.237910	1	1	13	Ulva (Sheet-like)	36	yes	73%	16.585	3.187
	-	-	-			13	Filamentous algae	36		73%	-	-
	-	-	-	10	10	29	Ulva (Sheet-like)	20	yes	41%	-	-
	End	117.396510	33.237900			29	Filamentous algae	20		41%	8.555	1.255
T2	Start	117.407910	33.235560	1	1	0	Ulva (Sheet-like)	49	yes	100%	10.333	1.602
	End	117.408020	33.235540	10	10	8	Ulva (Sheet-like)	41	yes	84%	9.685	1.5125
T3	Station inaccessible because of water depth			-	-	-	-	-	-	-	-	-

Figure 27. Example photos of macroalgal cover observed in the upper lagoon in March (top photo) and in the lower lagoon in October (bottom photo).

4. SUMMARY AND CONCLUSIONS

This project's main objective was to provide a long-term water quality dataset of sufficient quality to calibrate a hydrodynamic and eutrophication numeric model for the lagoon. This objective was met. The year-long depth, temperature, conductivity, pH, and dissolved oxygen dataset collected at 15-min intervals was sufficient to resolve variations at sub-tidal, daily, and seasonal time scales. The collection and analysis of discrete water samples for nutrients, total suspended solids, and chlorophyll-*a*, spatial mapping, and benthic macroalgal data during two index periods provided important calibration data for the modeling effort, insight as to sources and processes affecting their spatial and temporal distribution, and should serve in the future to help in developing site-specific water quality objectives.

The dataset was not without some gaps and data issues. Most importantly, the data collection was interrupted for a month-long period in June during construction of an earthern berm to support a new railroad bridge in the lower lagoon. This data gap could not be avoided. There was also about a two-week data gap that occurred when the sensor package was knocked out of the water during a set of intense storms in December, a gap that also could not be avoided. The bridge construction also led to a requirement to move the lower lagoon monitoring location half way through the data collection. The site was moved 600 feet upstream along the side of the lagoon. This second site was found to be generally representative of lower lagoon water quality for most parameters under open lagoon flow conditions. However, dissolved oxygen was found to be lower than what might be found mid-stream during some periods of low/no-flow particularly when the lagoon mouth was closed October through December. The results showed that some of the low (and zero) oxygen levels observed during a few weeks of the mouth closure, while accurate, were lower than what would have been observed in other parts of the Lower lagoon. Additionally, TDN, TDP, and TPP were not measured during Index Period 2 were inadvertently not collected. That gap could have been avoided if the analyte list had been more specifically listed in the custody sheets. And finally, benthic macroalgae data were not possible to collect once the lagoon mouth had closed because the data needed to be collected at low tide, another data gap that could not be avoided.

Despite the data gaps and issues, there were sufficient data to understand the main drivers of water quality occurring in the lagoon. The data describe a lagoon that was strongly dominated by its connection with tidal flow from the ocean. Daily fluctuations in water quality were primarily a result of tidal mixing of ocean water and river flow. Dissolved oxygen and pH fluctuations had a strong diurnal component which was consistent with diurnal algal production and respiration processes. The lack of tidal exchange during the mouth closure provided a dataset in which the primary daily variation was the diurnal signal.

The lagoon had strong seasonal variations in water quality conditions driven by decreasing freshwater flow, summertime heating, longer daylight hours, and a reduction in tidal flow as a result of natural berm building at the lagoon-ocean boundary. These effects were particularly strong when the mouth closed completely in October. The result was a lagoon that was considerably warmer and saltier with reduced freshwater flow and generally smaller daily variations in summer/fall than observed in winter/spring. The observed seasonal changes generally were much greater than the spatial variations observed between the lower and upper lagoon.

The main influence of ocean water exchange was observed to about the Railroad Bridge. The main influence of the freshwater river was observed about half way between the Railroad Bridge and the Stuart Mesa Bridge. In between the two locations is a transition region where mixing of fresh and saltwater is most intense. Previous spatial mapping surveys conducted during specific tide stages

(SSC Pacific [now SSC Pacific], 2007) showed that the location of this transition region is not static, moving slightly up- or downstream with flood and ebb tide, respectively.

The observed seasonal changes in nutrient concentrations reflect changes in sources as well as uptake and transformations by the biota. Total nitrogen levels in the lagoon were significantly higher in March than in October. At that time nitrate made up an average of 69% of the total nitrogen with dissolved organic nitrogen making up an average of about 21%. The October levels of total nitrogen were roughly a factor of two lower and were on average made up of 54% dissolved organic nitrogen and about 40% particulate nitrogen, with nitrate making up only a 3% of the total. Concentrations increased moving upstream in March but there were no spatial trends during the time of lagoon closure in October. The shift in distribution, concentration levels, and speciation suggest that the winter/spring wet season was a time of nitrogen influx primarily as nitrate. As the dry season progressed, the upstream nitrate source was reduced and the remaining amount was further reduced through uptake by the algae. What was found in the lagoon in October was primarily organic and particulate nitrogen that was generated by the decomposition of the biota during the period of higher algal productivity as observed by the increase in benthic macroalgae as well as higher concentrations of chlorophyll-*a*.

About 80% of the total nitrogen concentrations found in March were above the Basin Plan limit of 1.0 mg/L, and primarily in the form of nitrate-nitrogen. The October levels were all below the limit and were primarily in the less useable form of organic or particulate nitrogen. Transformation of this nitrogen would likely be a continuing source of nitrogen through the remainder of the year.

Total phosphorous levels in the lagoon were significantly higher in October than in March. Ortho-phosphorous on average made up roughly 60% of the total during both time periods. In contrast to nitrogen, there was no spatial trend in phosphorous concentrations in March but levels did increase upstream in October. The shift in distribution, concentration levels, and speciation suggest that there was a continuing source of phosphorous to the lagoon in October that was above the assimilative capacity of the algae. The concentrations of total phosphorous were above the Basin Plan limit of 0.1 mg/L in all samples.

Lagoon chlorophyll-*a* and benthic macroalgal biomass concentrations increased significantly from March into October. Chlorophyll-*a* concentrations tripled in October while benthic macroalgal biomass went from near zero in March to between 40 and 100% cover later in the year. The increase in algae was a result of higher light, temperature, and nutrient loading along with a reduction in scouring that occurs during winter storms. The higher levels of primary production by the algae in October resulted in the lower level of total nitrogen concentrations in the water, and because of the increased respiration demand, resulted in lower dissolved oxygen daily minima. The levels in summer fell below the 5 mg/L water quality objective in the San Diego Basin Plan 16% of the time, primarily at night and very early morning.

Based on the Basin Plan limits of N, P, and dissolved oxygen, the lagoon can be classified as intermittently impaired from eutrophication. Nitrogen and phosphorous limits were exceeded in March. Phosphorous limits were also exceeded in October. Dissolved oxygen intermittently went below the 5 mg/L limit in from spring to late fall. These results were consistent with observations made in other studies (SSC San Diego [now SSC Pacific], 2007; CDM, 2009; SCCWRP, 2010). These other studies provide a similar picture of the overall findings described here. Variations in annual river flow and/or nutrient loading adds to this variability. Lagoon modeling should provide the ability to capture the range in expected conditions and help in identifying under what conditions the lagoon may be impaired. These nutrient predictions should provide a basis for establishing lagoon-specific water quality objectives.

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14. ABSTRACT

This report describes water quality monitoring data collected in the Santa Margarita Lagoon in between February 2010 and February 2011 by the Navy's Environmental Sciences Branch of the Space and Naval Warfare Systems Center Pacific. The data collection was requested by watershed stakeholders to fulfill a San Diego Regional Water Quality Control Board Investigative Order related to potential eutrophication impairment. The objectives of the project were to provide a long-term water quality dataset that can be used for calibrating a hydrodynamic and eutrophication numeric model of the lagoon and to gain a more complete understanding of lagoon dynamics and physiochemical processes. The general technical approach followed the work plan developed by Investigative Order. The technical elements included collecting a one-year water quality dataset including depth, temperature, conductivity, pH, and dissolved oxygen using electronic sensors at a fixed location, and collecting discrete nutrient water samples, benthic algae, and performing spatial mapping during two index periods. The data showed a lagoon that was strongly dominated by its connection with tidal flow from the ocean. The lagoon had strong seasonal variations in water quality conditions driven by decreasing freshwater flow, summertime heating, longer aylight hours, and a reduction in tidal flow as a result of natural berm building at the lagoon-ocean boundary. Seasonal changes in nutrient concentrations reflected changes in sources and uptake and transformations by the biota. The observed seasonal changes generally were much greater than the spatial variations observed between the lower and upper lagoon. Based on the Basin Plan limits of N, P, and dissolved oxygen, the lagoon can be classified as intermittently impaired from eutrophication.

15. SUBJECT TERMS

Santa Margarita Lagoon   water quality dataset   index periods   spatial mapping   discrete water sampling
hydrodynamic/eutrophication numeric model   total maximum daily load   benthic algae sampling

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